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POLYMERS

M.Sc. IV SEM

- Brief and Intensive Notes
- Multiple Choice Questions

Based On NEP 2020

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Subject - Chemistry

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SYLLABUS

UNIT I. Basics Importance of polymers basic concepts; Monomers, repeat units, degree of polymerization, Linear, branched and network polymers, classification of polymers. Polymerization: condensation, addition, radical chain-ionic and co-ordination and copolymerization. Polymerization conditions and polymer reactions. Polymerization in homogeneous and heterogeneous systems.

UNIT II. Polymer Characterization Polydispersion - Average molecular weight concept. Number, weight and viscosity average molecular weights. Polydispersity and molecular weight distribution. The practical significance of molecular weight. Measurement of molecular weights. Endgroup, viscosity, light scattering, osmotic and ultracentrifugation methods Analysis and testing of polymers-chemical analysis of polymers, spectroscopic methods, X-ray diffraction study, Microscopy. Thermal analysis and physical testing-tensile strength. Fatigue. impact. Tear resistance. Hardness abrasion resistance.

UNIT III. Structure and Properties Morphology and order in crystalline polymers-configurations of polymer chains. Crystal structures of polymers, morphology of crystalline polymers, strain-induced morphology, crystallization and melting. Polymer structure and physical properties crystalline melting point Tm. melting points of homogeneous series, effect of chain flexibility and other steric factors, entropy and heat of fusion. The glass transition temperature, Tg relationship between Tm and Tg effects of molecular weight diluents, chemical structure, chain topology, branching and cross linking, property requirements and polymer utilization.

UNIT IV. Polymer Processing Plastics, elastomers and fibres. Compounding Processing Techniques; Calendering, die casting, rotational casting. film casting, injection moulding, blow moulding, extrusion moulding, thermoforming, foaming, reinforcing and fibre spinning.

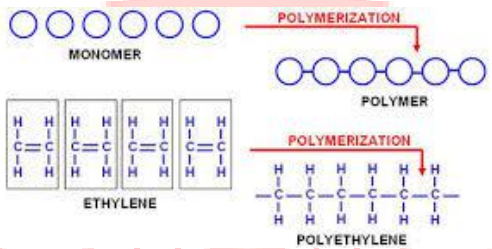
UNIT V. Properties of Commercial Polymers Polyethylene, polyvinyl chloride, polyamides, polyesters, phenolic resins, epoxy resins and silicon polymers. Functional polymers - Fire retarding polymers and electrically conducting polymers. Biomedical polymers-contact lens, dental polymers artificial heart, kidney, skin and blood cells.

UNIT I

Basics and Importance of Polymers

Definition:

Polymers are large molecules (macromolecules) composed of repeating structural units called repeat units. These repeat units are derived from smaller molecules called monomers through a process known as polymerization.



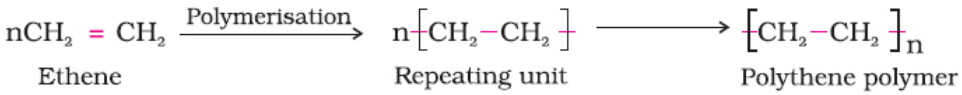
Importance of Polymers:

- **Versatility of Properties:** Can be tailored for flexibility, toughness, heat resistance, chemical inertness, and optical clarity.
- **Lightweight:** High strength-to-weight ratio makes them suitable for aerospace, automotive, and packaging.
- **Corrosion Resistance:** Ideal for chemical containers, pipes, and coatings.
- **Low Cost & Processability:** Easily shaped into fibers, films, foams, or molded parts.
- **Applications:** Polymers are used in packaging (polyethylene, polypropylene) for bags and containers, textiles (nylon, polyester) for durable fabrics, electronics (conducting polymers) for flexible circuits, medicine (biodegradable sutures, drug delivery), and construction (PVC pipes, acrylic sheets) for durable, weather-resistant materials.

Basic Concepts in Polymer Science

- **Monomer and repeating unit**: Polymer science deals with the study of macromolecules formed by the chemical joining of small units called **monomers**. These monomers link together through polymerization to form long chains, with each repeating chemical

segment known as a **repeat unit**. **Example:** Ethylene (CH_2=CH_2) → polyethylene, Vinyl chloride (CH_2=CHCl) → Polyvinylcloride



- **Degree of Polymerization (DP):**

$$Dp = \frac{\text{Molecular Weight of Polymer}}{\text{Molecular Weight of Repeat Unit}}$$

Higher DP usually means higher molecular weight and improved mechanical properties.

Example: If polyethylene has a molar mass of 140,000 and the repeat unit has 28 g/mol,

$$Dp = \frac{14000}{28} = 5000$$

Classification based on Source:

Natural polymers- These polymers are found in plants and animals. Examples are proteins, cellulose, starch, some resins and rubber.

Semi-synthetic polymers- Cellulose derivatives as cellulose acetate (rayon) and cellulose nitrate, etc. are some examples.

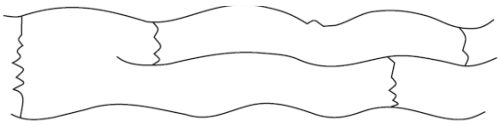
Synthetic Polymers- A variety of synthetic polymers as plastic (polythene), synthetic fibres. Examples: - (nylon 6, 6) and synthetic rubbers (Buna - S) are polymers extensively used in daily life as well as in industry.

Classification based on Structure of polymers: There are three different types based on the structure of the polymers.

Linear Polymers: - These polymers consist of long and straight chains. The examples are high density polythene, polyvinyl chloride, etc. These are represented as:

Branched chain polymers: - These polymers contain linear chains having some branches, e.g. low-density polythene. These are depicted as follows:

Cross linked or Network polymers: - The are usually formed from bi-functional and tri-functional monomers and contain strong covalent bonds between various linear polymer chains, e.g. Bakelite, melamine, etc. These polymers are depicted as follows:



Classification on the basis of mode of polymerisation

1. Addition polymers: - The addition polymers are formed by the repeated addition of monomer molecules possessing double or triple bonds.

For example: - The formation of polythene from Ethene and polypropene from propene.

- However, the addition polymers formed by the polymerisation of a single monomeric species are known as homopolymers. For example: - polythene.

$$n\ CH_2{=}CH_2 \rightarrow (CH_2\text{-}CH_2)_n$$

Ethene Polythene Homopolymer

- The polymers made by addition polymerisation from two different monomers are termed as copolymers, e.g., Buna-S, Buna-N, etc.

$$nCH_2 = CH\text{-}CH = CH_2 + nC_6H_5CH{=}CH_2 \rightarrow (CH_2\text{-}CH{=}CH\text{-}C_6H_5\text{-}CH_2\text{-}CH\text{-}CH_2)_n$$

1, 3-Butadiene Styrene Butadiene- styrene copolymer (Buna- S)

2. Condensation polymers

- The condensation polymers are formed by repeated condensation reaction between two different bi-functional or tri-functional monomeric units.
- In these polymerisation reactions, the elimination of small molecules such as water, alcohol, hydrogen chloride, etc. take place.
  - The examples are Terylene (Dacron), nylon 6, 6, nylon 6, etc.
  - For example, nylon 6, 6 is formed by the condensation of hexamethylene diamine with adipic acid.

Classification based on Molecular forces

A large number of polymers can be used in different fields because of their mechanical properties like tensile strength, elasticity, toughness etc.

- These mechanical properties are governed by intermolecular forces, e.g., van der Waals forces and hydrogen bonds, present in the polymer. These forces also bind the polymer chains.
- The polymers are classified into the following four sub groups on the basis of magnitude of intermolecular forces present in them.

1) Elastomers: These are rubber like solids with elastic properties. The polymer chains are held together by the weakest intermolecular forces. These weak binding forces permit the polymer to be stretched. A few 'crosslinks' are introduced in between the chains, which help the polymer to retract to its original position after the force is released as in vulcanised rubber. The examples are Buna-S, Buna-N, neoprene, etc.

2) Fibres: Fibres are the thread forming solids which possess high tensile strength and high modulus. These characteristics can be attributed to the strong intermolecular forces like hydrogen bonding. These strong forces also lead to close packing of chains and thus impart crystalline nature. The examples are polyamides (nylon 6, 6), polyesters (terylene), etc.

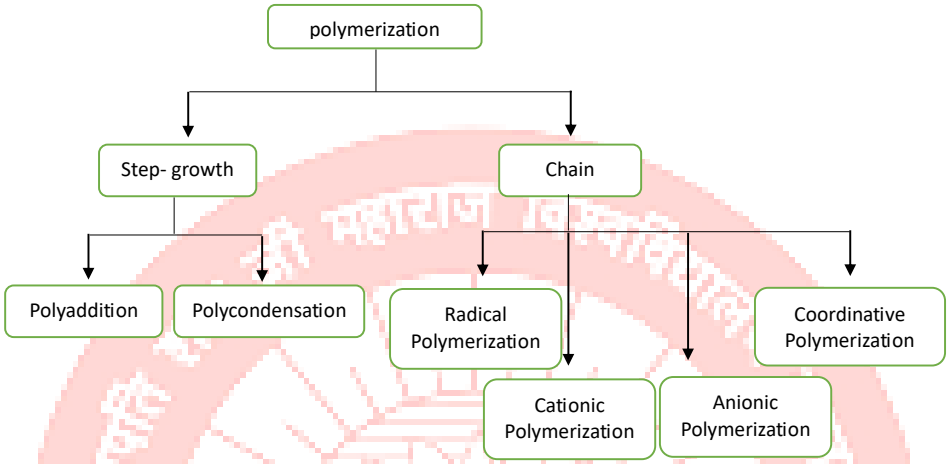
3) Thermoplastic Polymers: These are the linear or slightly branched long chain molecules capable of repeatedly softening on heating and hardening on cooling. These polymers possess intermolecular forces of attraction intermediate between elastomers and fibres. Some common thermoplastics are polythene, polystyrene, polyvinyl, etc.

4) Thermosetting Polymers: These polymers are cross linked or heavily branched molecules, which on heating undergo extensive cross linking in moulds and again become infusible. These cannot be reused. Some common examples are Bakelite, urea-formaldehyde resins, etc.

Types of Polymerization Reactions

There are broadly two types of polymerization reactions:

1. Addition or chain growth polymerization
2. Condensation or step growth polymerization



1. Addition or chain growth polymerization

The molecules of the same monomer or different monomers add together on a large scale to form a polymer. The monomers used are unsaturated compounds, e.g., alkenes, alkadienes and their derivatives.

- This mode of polymerisation leading to an increase in chain length or chain growth can take place through the formation of either free radicals or ionic species.

However, the free radical governed addition or chain growth polymerisation is the most common mode.

1.1 Free Radical Polymerization

1.2 Cationic polymerization

1.3 Anionic Polymerization

1.1 Free Radical Mechanism:

Many of alkenes or dienes and their derivatives are polymerized in the presence of a free radical (catalyst) like benzoyl peroxide.

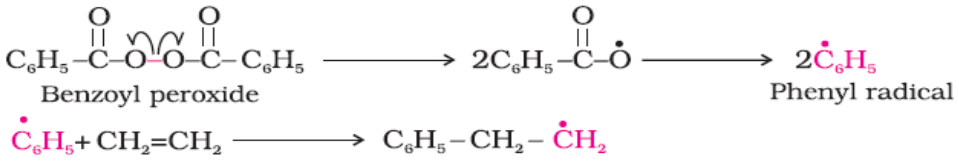
The sequence of steps may be depicted as follows:

- Chain initiation steps
- Chain propagating step
- Chain terminating step

For example: The polymerisation of Ethene to polythene consists of heating or exposing to light a mixture of Ethene with a small amount of benzoyl peroxide initiator.

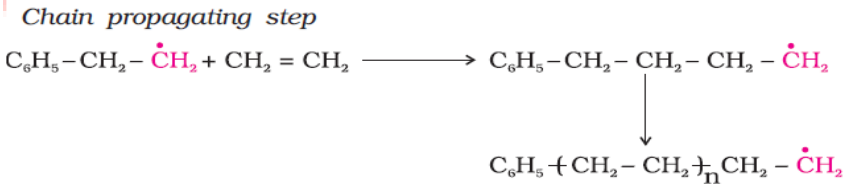
Chain initiating step-The process starts with the addition of phenyl free radical formed by the peroxide to the Ethene double bond thus generating a new and larger free radical. This step is called chain initiating step.

Chain initiation steps

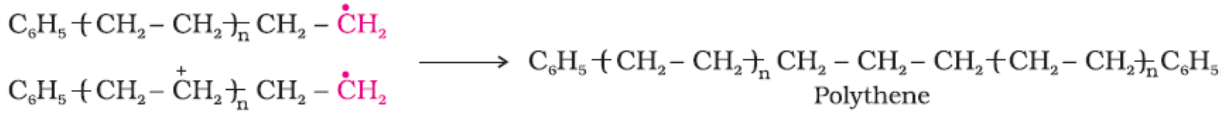


Chain propagating step - As this radical reacts with another molecule of Ethene, another bigger sized radical is formed. The repetition of this sequence with new and bigger radicals carries the reaction forward and the step is termed as chain propagating step.

Chain propagating step



Ultimately, at some stage the product radical thus formed reacts with another radical to form the polymerised product. This step is called the chain terminating step.



1.2 Cationic polymerization

Initiator system:

- tert-Butyl chloride + $AlCl_3$ (Lewis acid) or H_2SO_4 (Bronsted acid)
- Generates **tert-butyl carbocation**.

Mechanism:

Initiation- The initiator (usually a Lewis acid or a strong proton donor) reacts with the monomer to generate a carbocation, which starts the chain reaction.

$$(CH_3)_3C–Cl + AlCl_3 \rightarrow (CH_3)_3C^+ + AlCl_4^-$$

Propagation- The carbocation at the chain end reacts with more monomer molecules, adding them one by one to grow the polymer chain.

$$(CH_3)_3C^+ + CH_2 = C(CH_3)_2 \rightarrow (CH_3)_3C–CH_2–C^+(CH_3)_2$$

$$(CH_3)_3C–CH_2–C^+(CH_3)_2 + CH_2 = C(CH_3)_2 \rightarrow \text{longer chain carbocation}$$

Termination- Unlike radical polymerization, termination is often less common, especially at low temperatures. It can occur via:

$$R^+ + H_2O \rightarrow R–OH$$

Kinetics: $R_p = k_p$ [monomer][carbocation]

Chain length controlled by **[monomer]/[initiator] ratio**.

1.3 Mechanism of Anionic Polymerization

a) Initiation-The initiator donates an electron to the monomer double bond, forming a carbanion.

Example: Styrene polymerization with n-butyllithium (n-BuLi)

$$CH_2 = CH–C_6H_5 + n\text{-BuLi} \rightarrow CH_2^-–CH(C_6H_5)–Li^+$$

The carbanion at the chain end is now active and ready for propagation.

b) Propagation- The carbanion attacks another monomer molecule, adding it to the chain and transferring the negative charge to the new chain end.

$$CH_2^-–CH(C_6H_5)–Li^+ + CH_2 = CH–C_6H_5 \rightarrow CH_2–CH(C_6H_5)–CH_2^-–CH(C_6H_5)–Li^+$$

Each monomer addition transfers the negative charge to the chain end.

c) Termination / Chain Transfer-In living anionic polymerization, termination is absent unless a proton donor (e.g., water, alcohol) is added:

$$R^- + H_2O \rightarrow R\text{–}H + OH^-$$

Chain transfer can occur if the active carbanion reacts with a solvent or impurity**.**

3. Kinetics of Anionic Polymerization -The polymerization rate depends on monomer and active chain concentration:

$$\mathbf{R_p = k_p[M][M^-]}$$

Where: k_p = propagation rate constant, $[M^-]$ = concentration of active carbanions, [M] = monomer concentration

Coordination polymerization- Coordination polymerization is a chain-growth polymerization in which a transition metal catalyst (like $TiCl_4 + Al(C_2H_5)_3$, Ziegler-Natta catalyst) coordinates with monomers such as ethylene or propylene. The monomer binds to the metal center, and during propagation, it inserts into the metal- carbon bond, growing the polymer chain. Termination is minimal, allowing high molecular weight and stereoregular polymers (isotactic or syndiotactic). This method is used industrially to produce polyethylene, polypropylene, and other polyolefins, with the polymerization rate depending on monomer and catalyst concentration.

Preparation of Important Addition Reaction

1. Polythene: -There are two types of polythene-

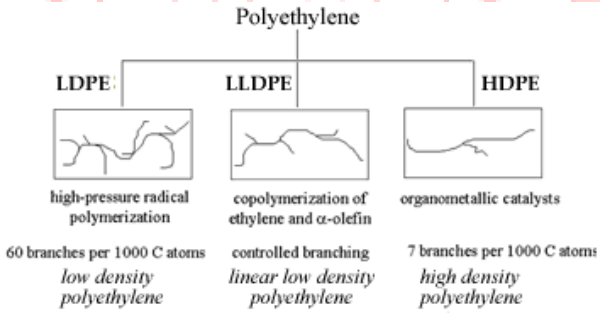
(i) Low density polythene:

- It is obtained by the polymerisation of Ethene under high pressure of 1000 to 2000 atmospheres at a temperature of 350 K to 570 K in the presence of traces of dioxygen or a peroxide initiator (catalyst).
- The low-density polythene (LDP) obtained through the free radical addition and H-atom abstraction has highly branched structure.

- Low density polythene is chemically inert and tough but flexible and a poor conductor of electricity.
- Hence, it is used in the insulation of electricity carrying wires and manufacture of squeeze bottles, toys and flexible pipes.

(ii) High density polythene:

- It is formed when addition polymerisation of Ethene takes place in a hydrocarbon solvent in the presence of a catalyst such as triethylaluminium and titanium tetrachloride (Ziegler-Natta catalyst) at a temperature of 333 K to 343 K and under a pressure of 6-7 atmospheres.
- High density polythene (HDP) thus produced, consists of linear molecules and has a high density due to close packing.
- It is also chemically inert and more tough and hard. It is used for manufacturing buckets, dustbins, bottles, pipes, etc.



2. Polytetrafluroethene (Teflon)

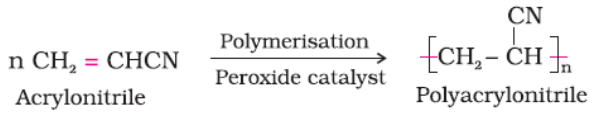
- Teflon is manufactured by heating tetrafluoroethene with a free radical or per sulphate catalyst at high pressures.

$$\underset{\text{Tetrafluoroethene}}{n\ CF_2 = CF_2} \xrightarrow[\text{High pressure}]{\text{Catalyst}} \underset{\text{Teflon}}{\left[CF_2 - CF_2\right]_n}$$

- It is chemically inert and resistant to attack by corrosive reagents. It is used in making oil seals and gaskets and also used for non-stick surface coated utensils.

3. Polyacrylonitrile

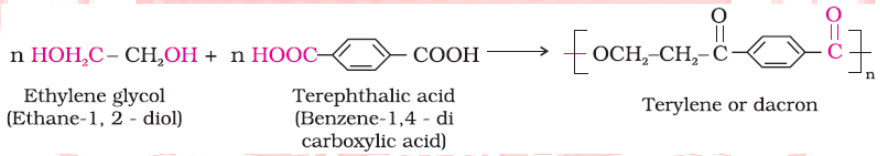
- The addition polymerisation of acrylonitrile in presence of a peroxide catalyst leads to the formation of polyacrylonitrile.



- Polyacrylonitrile is used as a substitute for wool in making commercial fibres as Orlon or acrilan.

2. Condensation Polymerization or step growth polymerization

- This type of polymerisation involves a repetitive condensation reaction between two bi-functional monomers.
- These poly condensation reactions result in the loss of some simple molecules as water, alcohol, etc., and lead to the formation of high molecular mass condensation polymers.
- In these reactions, the product of each step is again a bi-functional species and the sequence of condensation goes on.
- Since, each step produces a distinct functionalised species and is independent of each other; this process is also called as step growth polymerisation.
- The formation of Terylene or Dacron by the interaction of ethylene glycol and terephthalic acid is an example of this type of polymerisation.

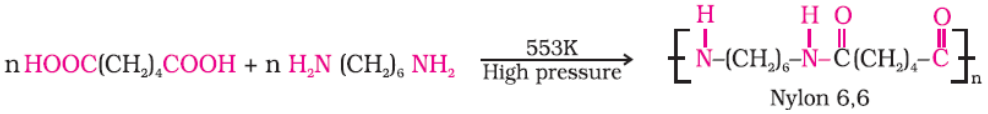


Preparation of Important Addition Reaction

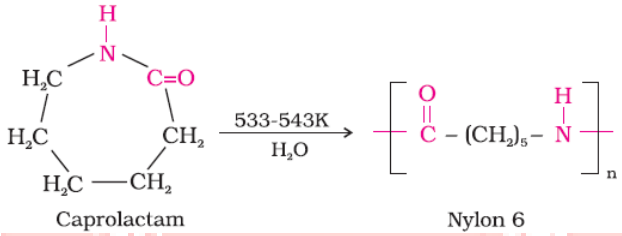
Polyamides: These polymers possessing amide linkages are important examples of synthetic fibres and are termed as nylons. The general method of preparation consists of the condensation polymerisation of diamines with dicarboxylic acids and also of amino acids and their lactams**.**

Preparation of Nylons

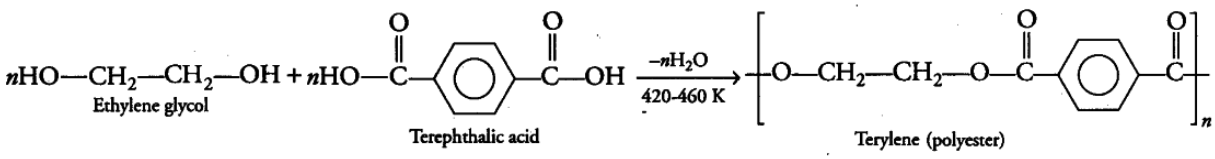
Nylon 6, 6: It is prepared by the condensation polymerisation of hexamethylenediamine with adipic acid under high pressure and at high temperature. Nylon 6, 6 is used in making sheets, bristles for brushes and in textile industry.



Nylon 6: It is obtained by heating Caprolactum with water at a high temperature. Nylon 6 is used for the manufacture of tyre cords, fabrics and ropes.



Polyesters: These are the poly condensation products of dicarboxylic acids and diols. **Dacron or Terylene** is the best-known example of polyesters. It is manufactured by heating a mixture of ethylene glycol and terephthalic acid at 420 to 460 K in the presence of Zinc acetate antimony trioxide catalyst. Dacron fibre (Terylene) is crease resistant and is used in blending with cotton and wool fibres and also as glass reinforcing materials in safety helmets, etc.



Examples of Polymers, its monomers and applications

Chemical Name and Trade Name(s)	**Monomer**	**Polymer**	**Typical Uses**
Polyethylene	$CH_2 = CH_2$	$-(CH_2 - CH_2)_n -$	Bottles, plastic bags, film
Polypropylene	$CH_2 = CH-(CH_3)$	$-(CH- CH-(CH_3)_n -$	Carpet fiber, pipes, bottles, artificial turf
Poly(vinyl chloride) (PVC)	$CH_2 = CHCl$	$-(CH_2 - CHCl)_n -$	Synthetic leather, floor tiles, garden hoses, water pipe
Polytetrafluoroethylene (Teflon→)	$CF_2 = CF_2$	$-(CF_2 - CF_2)_n -$	Pan coatings, plumbers tape, heart valves, fabrics
Poly(methyl methacrylate) (Lucite→, Plexiglas→)	$CH_2 = C(CH_3)C(=O)-O-CH_3$	$-(CH_2 - C(CH_3)C(=O)-O-CH_3)_n -$	Airplane windows, paint, contact lenses, fiber optics
Poly(vinyl acetate)	$CH_2 = CH-O-C(=O)-CH_3$	$-(CH_2 - CH-O-C(=O)-CH_3)_n -$	Adhesives, latex paint, chewing gum
Polyacrylonitrile (Orlon→, Acrilan→)	$CH_2 = CH-CN$	$-(CH_2 - CH-CN)_n -$	Carpets, fabrics
Polystyrene (Styrofoam→)	$CH_2 = CHC_6H_5$	$-(CH_2-CHC_6H_5)_n -$	Food coolers, drinking cups, insulation

1. Polymers are made of:

a) Single atoms

b) Many small units joined together

c) Simple ions

d) None of these

Ans: b) Many small units joined together

2. Which type of bond joins the units in a polymer?

a) Ionic bond

b) Covalent bond

c) Hydrogen bond

d) Metallic bond

Ans: b) Covalent bond

3. Polymers are also called:

a) Macromolecules

b) Micromolecules

c) Molecules

d) Atoms

Ans: a) Macromolecules

4. A polymer formed from two different monomers is called:

a) Homopolymer

b) Copolymer

c) Block polymer

d) Random polymer

Ans: b) Copolymer

5. Which of the following is a synthetic polymer?

a) Starch

b) Cellulose

c) Bakelite

d) Silk

Ans: c) Bakelite

6. Polyethylene is an example of a:

a) Linear polymer

b) Branched polymer

c) Network polymer

d) Crosslinked copolymer

Ans: a) Linear polymer

7. Bakelite is an example of:

a) Linear polymer

b) Branched polymer

c) Network polymer

d) Thermoplastic

Ans: c) Network polymer

8. The term “macromolecule” refers to:

a) Molecules with small molecular weight

b) Very large molecules with high molecular weight

c) Mixture of small molecules

d) Low degree of polymerization

Ans: b) Very large molecules with high molecular weight

9. Which of the following is not a polymer?

a) Cellulose

b) Starch

c) Sodium chloride

d) Nylon-6,6

Ans: c) Sodium chloride

10. Branched polymers differ from linear polymers mainly in:

a) Monomer type

b) Molecular architecture

c) Color

d) Degree of polymerization

Ans: b) Molecular architecture

11. The repeating unit in polyethylene is:

a) $–CH_2–CH_2–$

b) –CH=CH–

c) $–C_6H_4–$

d) –NH–CO–

Ans: a) $–CH_2–CH_2–$

12. Which polymer type forms a three-dimensional network structure?

a) Linear polymer

b) Branched polymer

c) Network polymer

d) Random copolymer

Ans: c) Network polymer

13. The degree of polymerization is defined as:

a) Number of chains in polymer

b) Number of monomers in a repeat unit

c) Number of repeat units in a polymer chain

d) Chain length in meters

Ans: c) Number of repeat units in a polymer chain

14. Which classification of polymers is based on their origin?

a) Natural, semi-synthetic, synthetic

b) Linear, branched, network

c) Thermoset, thermoplastic, elastomer

d) Addition, condensation

Ans: a) Natural, semi-synthetic, synthetic

15. Which of these is a natural polymer?

a) PVC

b) Nylon

c) Silk

d) Teflon

Ans: c) Silk

16. Polymers that can be remolded upon heating are called:

a) Thermosets

b) Thermoplastics

c) Elastomers

d) Fibers

Ans: b) Thermoplastics

17.Which of the following is an elastomer?

a) Polystyrene

b) Neoprene rubber

c) Polypropylene

d) Nylon

Ans: b) Neoprene rubber

18. Styrene–butadiene rubber (SBR) is a:

a) Homopolymer

b) Random copolymer

c) Alternating copolymer

d) Graft copolymer

Ans: b) Random copolymer

19. In block copolymers, monomers are:

a) Randomly arranged

b) In alternating sequence

c) Arranged in long blocks of each type

d) Crosslinked only

Ans: c) Arranged in long blocks of each type

20. A polymer with one type of monomer forming the backbone and another type grafted as side chains is called:

a) Alternating copolymer

b) Graft copolymer

c) Random copolymer

d) Block copolymer

Ans: b) Graft copolymer

21. Which property is most affected by copolymer composition?

a) Density only

b) Mechanical, thermal, and chemical properties

c) Color only

d) Optical clarity only

Ans: b) Mechanical, thermal, and chemical properties

22. Acrylonitrile–butadiene–styrene (ABS) is a:

a) Ternary copolymer

b) Homopolymer

c) Elastomer only

d) Thermoset only

Ans: a) Ternary copolymer

23. In condensation polymerization, monomers join together by eliminating:

a) H_2O or small molecules

b) O_2

c) Catalyst

d) None of the above

Ans: a) H_2O or small molecules

24. Addition polymerization is also called:

a) Chain-growth polymerization

b) Step-growth polymerization

c) Condensation polymerization

d) Cross-linking

Ans: a) Chain-growth polymerization

25. In radical chain polymerization, the first step is:

a) Propagation

b) Initiation

c) Termination

d) Combination

Ans: b) Initiation

26. Ziegler–Natta catalysts are used in:

a) Radical polymerization

b) Ionic polymerization

c) Coordination polymerization

d) Condensation polymerization

Ans: c) Coordination polymerization

27. Temperature, pressure, and catalyst mainly affect:

a) Monomer structure

b) Polymerization rate and molecular weight

c) Polymer crystallinity only

d) Chain length only

Ans: b) Polymerization rate and molecular weight

28. Crosslinking in polymers generally:

a) Reduces strength

b) Increases melting point

c) Makes them more soluble

d) Converts thermoset to thermoplastic

Ans: b) Increases melting point

29. In homogeneous polymerization, monomers and catalysts are:

a) In separate phases

b) In the same phase

c) Always in solid form

d) Always in gaseous form

Ans: b) In the same phase

30. Suspension polymerization is an example of:

a) Homogeneous polymerization

b) Heterogeneous polymerization

c) Ionic polymerization

d) Solid-state polymerization

Ans: b) Heterogeneous polymerization

31. Emulsion polymerization uses:

a) Organic solvents only

b) Water and surfactants

c) Solid catalysts only

d) No catalyst

Ans: b) Water and surfactants

32. Step-growth polymerization involves:

a) Radical initiators only

b) Reaction between functional groups of monomers

c) No small molecule elimination

d) Only one type of monomer

Ans: b) Reaction between functional groups of monomers

33. Which of the following is an example of condensation polymer?

a) Polyethylene

b) Polyvinyl chloride

c) Nylon-6,6

d) Polystyrene

Ans: c) Nylon-6,6

34. Free radical polymerization requires:

a) UV light or heat

b) Strong acids only

c) Metal catalysts only

d) Enzymes only

Ans: a) UV light or heat

35. In ionic polymerization, the growing chain end is:

a) Electrically neutral

b) Charged (positive or negative)

c) Always radical in nature

d) Metallic

Ans: b) Charged (positive or negative)

36. The sequence distribution of monomers in a copolymer determines:

a) Degree of polymerization only

b) Physical and chemical properties

c) Color only

d) Monomer size

Ans: b) Physical and chemical properties

37. Increasing polymerization temperature generally:

a) Always increases molecular weight

b) May reduce molecular weight in radical polymerization

c) Has no effect on polymerization

d) Stops polymerization

Ans: b) May reduce molecular weight in radical polymerization

38. Chain transfer reaction in polymerization:

a) Stops polymer growth permanently

b) Transfers active centre to another molecule

c) Has no effect on molecular weight

d) Occurs only in ionic polymerization

Ans: b) Transfers active centre to another molecule

39. Crosslinking in vulcanization of rubber is achieved using:

a) Sulfur

b) Oxygen

c) Nitrogen

d) Chlorine

Ans: a) Sulfur

40. Which of these is an example of thermosetting polymer?

a) Polyethylene

b) Polypropylene

c) Bakelite

d) Polystyrene

Ans: c) Bakelite

41. Bulk polymerization is an example of:

a) Homogeneous polymerization

b) Heterogeneous polymerization

c) Step polymerization only

d) None of the above

Ans: a) Homogeneous polymerization

42. Suspension polymerization produces polymers as:

a) Films

b) Beads or granules

c) Fibers

d) Sheets

Ans: b) Beads or granules

43. Which method uses micelles to stabilize monomers in water?

a) Bulk polymerization

b) Emulsion polymerization

c) Solution polymerization

d) Solid-state polymerization

Ans: b) Emulsion polymerization

44. In solution polymerization, the solvent mainly acts as:

a) Reactant

b) Heat transfer medium and viscosity controller

c) Crosslinking agent

d) Initiator

Ans: b) Heat transfer medium and viscosity controller

45. Emulsion polymerization generally gives:

a) High molecular weight polymers at low viscosity

b) Low molecular weight polymers at high viscosity

c) No control over properties

d) Only thermosetting polymers

Ans: a) High molecular weight polymers at low viscosity

46. In step-growth polymerization, molecular weight builds up:

a) Rapidly in early stages

b) Slowly, reaching high values only at high conversion

c) Constantly throughout

d) Only during termination

Ans: b) Slowly, reaching high values only at high conversion

47. Addition polymerization requires:

a) Unsaturated monomers

b) Bifunctional saturated monomers

c) Monomers with acid groups

d) Monomers with base groups

Ans: a) Unsaturated monomers

48. Which is not a step in free radical polymerization?

a) Initiation

b) Propagation

c) Termination

d) Cyclization

Ans: d) Cyclization

49. Anionic polymerization is initiated by:

a) Peroxides

b) Alkali metals or organometallic compounds

c) UV light

d) Transition metal complexes

Ans: b) Alkali metals or organometallic compounds

50. Cationic polymerization is favoured by:

a) Electron-withdrawing groups on monomer

b) Electron-donating groups on monomer

c) Saturated hydrocarbons

d) Metals only

Ans: b) Electron-donating groups on monomer

51. Which method is best for controlling exothermic heat during polymerization?

a) Bulk polymerization

b) Suspension or emulsion polymerization

c) Solid-state polymerization

d) Gas-phase polymerization

Ans: b) Suspension or emulsion polymerization

52. Chain termination in radical polymerization can occur by:

a) Combination or disproportionation

b) Oxidation only

c) Addition of catalyst

d) Cyclization

Ans: a) Combination or disproportionation

53. Depolymerization is the reverse of:

a) Polymerization

b) Chain scission

c) Vulcanization

d) Copolymerization

Ans: a) Polymerization

54. A catalyst that produces stereoregular polymers is called:

a) Radical initiator

b) Ziegler–Natta catalyst

c) Lewis base

d) Cationic initiator

Ans: b) Ziegler–Natta catalyst

55. Which is a post-polymerization modification?

a) Chain transfer

b) Sulfonation of polystyrene

c) Radical initiation

d) Coordination catalysis

Ans: b) Sulfonation of polystyrene

56. In suspension polymerization, monomers are dispersed in:

a) Oil

b) Water

c) Organic solvent

d) Air

Ans: b) Water

57. In emulsion polymerization, the reaction occurs mainly:

a) In the continuous phase

b) Inside micelles

c) On catalyst surface only

d) In vapor phase

Ans: b) Inside micelles

58. Natural polymers include:

a) Nylon and Polyester

b) Rubber, Proteins, and Starch

c) Bakelite and Teflon

d) PVC and Polyethylene

Ans: b) Rubber, Proteins, and Starch

59. Synthetic polymers include:

a) Starch and Cellulose

b) Proteins and DNA

c) Nylon and Bakelite

d) Rubber and Silk

Ans: c) Nylon and Bakelite

60. Which polymer is used in making bottles and containers?

a) Nylon

b) Polyethylene

c) Silk

d) Cellulose

Ans: b) Polyethylene

61. Proteins are polymers of:

a) Sugars

b) Amino acids

c) Fatty acids

d) Nucleotides

Ans: b) Amino acids

62. Polymerization is the process of:

a) Breaking a polymer into small units

b) Joining small units to form a polymer

c) Melting polymers

d) None of these

Ans: b) Joining small units to form a polymer

63. Which polymer is used in making bulletproof jackets?

a) Nylon

b) Kevlar

c) Rubber

d) Polyethylene

Ans: b) Kevlar

64. Polyesters are polymers formed by:

a) Addition reaction

b) Condensation reaction

c) Oxidation reaction

d) Hydrolysis

Ans: b) Condensation reaction

65. Vulcanization of rubber is done to:

a) Make it softer

b) Increase elasticity and strength

c) Melt it

d) Change its colour

Ans: b) Increase elasticity and strength

66. Nylon-6,6 is made by polymerization of:

a) Hexane and hexanol

b) Hexamethylene diamine and adipic acid

c) Ethylene and benzene

d) Vinyl chloride

Ans: b) Hexamethylene diamine and adipic acid

67. Which of the following is a thermosetting polymer?

a) Bakelite

b) Polythene

c) Nylon

d) Rubber

Ans: a) Bakelite

68. Which of the following is a thermoplastic polymer?

a) Bakelite

b) Teflon

c) PVC

d) Vulcanized rubber

Ans: c) PVC

69. Which of the following is a thermosetting polymer?

a) Polyethylene

b) Polystyrene

c) Bakelite

d) PVC

Ans: c) Bakelite

70. Synthetic rubbers are made by polymerizing:

a) Ethylene

b) Isoprene

c) Propylene

d) Styrene

Ans: b) Isoprene

71. The main difference between addition and condensation polymers is:

a) Addition polymers are natural, condensation polymers are synthetic

b) Addition polymers form without losing small molecules, condensation polymers release small molecules

c) Addition polymers are always solids, condensation polymers are always liquids

d) There is no difference

Ans: b) Addition polymers form without losing small molecules, condensation polymers release small molecules

72. Rubber becomes more useful after:

a) Heating

b) Vulcanization

c) Dissolving in water

d) Freezing

Ans: b) Vulcanization

73. The repeating unit in polythene is:

a) $–CH_2–CH_2–$

b) $–C_2H_4O–$

c) $–CH_2–O–CH_2–$

d) –CH–CH–

Ans: a) $–CH_2–CH_2–$

74. Polymers used for making fabrics include:

a) Nylon and Polyester

b) PVC and Polythene

c) Bakelite and Teflon

d) Rubber and Cellulose

Ans: a) Nylon and Polyester

75. Proteins are formed by:

a) Condensation of amino acids

b) Addition of glucose units

c) Polymerization of nucleotides

d) Joining fatty acids

Ans: a) Condensation of amino acids

76. Teflon is used because it is:

a) Flexible

b) Non-stick and resistant to chemicals

c) Stretchable

d) Biodegradable

Ans: b) Non-stick and resistant to chemicals

77. Nylon belongs to which type of polymer?

a) Addition polymer

b) Condensation polymer

c) Natural polymer

d) Biopolymer

Ans: b) Condensation polymer

78. Polyvinyl chloride (PVC) is primarily used in:

a) Clothing

b) Pipes and cables

c) Rubber bands

d) Food packaging

Ans: b) Pipes and cables

79. The main monomer of polystyrene is:

a) Styrene

b) Ethylene

c) Propylene

d) Vinyl chloride

Ans: a) Styrene

80. Vulcanized rubber contains:

a) Sulfur bridges

b) Oxygen bridges

c) Hydrogen bonds

d) None of these

Ans: a) Sulfur bridges

81. Polymers that can be remelted and reshaped are called:

a) Thermosetting polymers

b) Thermoplastic polymers

c) Elastomers

d) Biopolymers

Ans: b) Thermoplastic polymers

82. Rubber becomes more useful after:

a) Melting

b) Vulcanization

c) Dissolving in water

d) Freezing

Ans: b) Vulcanization

83. Which polymer is used in non-stick cookware?

a) Nylon

b) Teflon

c) PVC

d) Bakelite

Ans: b) Teflon

84. Polymers like DNA and proteins are called:

a) Synthetic polymers

b) Natural polymers

c) Biopolymers

d) Thermoplastics

Ans: c) Biopolymers

85. Which polymer is used in making ropes, fabrics, and fishing nets?

a) Nylon

b) Bakelite

c) Polythene

d) Teflon

Ans: a) Nylon

UNIT -II

The molecular weight of a polymer depends upon the number of simple molecules joined together during polymerization reaction *i.e.,* upon the degree of polymerization. A polymer consists of molecules of different molecular weights and hence, its molecular weight is expressed in term of an "average" value. There are four types of average molecular weights.

1. The Number Average Molecular Weight (M_n)
2. The Weight Average Molecular Weight (M_w)
3. The sedimentation Average Molecular Weight (M_z)
4.The Viscosity Average Molecular Weight (M_v)

1. The Number Average Molecular Weight (M_n) is the simplest way to describe the average size of molecules in a sample, especially in polymers. It is calculated by dividing the total weight of all molecules by the total number of molecules present.

Mathematically: $$\mathbf{M_n} = \frac{\sum NiMi}{\sum Ni}$$

Where, N_i = number of molecules having molecular weight, M_i = molecular weight of molecule type

The molecular weight obtained from end group analysis and measurement of colligative properties like osmotic pressure are the number average molecular weights of the polymer.

2. The Weight Average Molecular Weight (M_w) is a way to describe the average molecular weight of a polymer, giving more weight to the heavier molecules in the distribution.

It is defined mathematically as:

$$\mathbf{Mw} = \frac{\sum \mathrm{Ni}Mi^2}{\sum \mathrm{NiMi}}$$

Where, N_i = number of molecules with molecular weight, M_i = molecular weight of species i

3. The sedimentation Average Molecular Weight (M_z):

$$\mathbf{M}z = \frac{\sum \mathrm{Ni} Mi^3}{\sum \mathrm{Ni} Mi^2}$$

Where, N_i = number of molecules with molecular weight M_i.

M_z weights the higher molecular weight species even more strongly than M_w. It is particularly relevant in **sedimentation** and **light scattering** measurements, because these techniques are sensitive to the larger molecules in a sample.

4. The Viscosity Average Molecular Weight (M_v):

$$\boldsymbol{Mv} = \left(\frac{\sum \mathrm{Ni} Mi^{1+a}}{\sum \mathrm{Ni} Mi}\right)^{1/a}$$

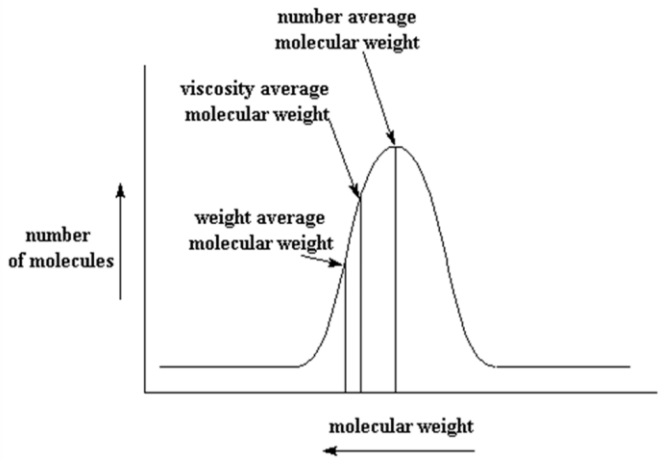
From intrinsic viscosity [η] using Mark–Houwink equation:

$$[\eta] = K\, \mathbf{M}_v^{a}$$

Where N_i is the number of molecules having molecular weight M_i and a is variable (range 0.5 to 1) in the Mark- Houwink equation.

Therefore: $\mathbf{M}_n \leq \mathbf{M}_v \leq \mathbf{M}_w \leq \mathbf{M}_z$

It is important that light scattering, osmotic pressure, ultracentrifugation and viscosity methods are used to get M_n, M_w, Mz and M_v respectively.



Degree of polymerisation (DP) Number of repeating unit in a polymer is called as degree of polymerisation (DP). DP represents the average number of monomer units in the polymer chain and is an alternate way of expressing average chain size of the polymer. DP provides the indirect method of expressing the molecular weight and the relation is as follows;

$$M = DP \times m$$

Where, M is the molecular weight of polymer, DP is the degree of polymerisation and m is the molecular weight of the monomer Both number average (DP_n) and weight average (DP_w) degree of polymerization can be defined as

$$(DP)_n = \frac{\sum n_i (DP)_i}{\sum n_i} \text{ and } (DP)_w = \frac{\sum n_i (DP)_i^2}{\sum n_i (DP)_i}$$

Polydispersity index (PDI)

Index of polydispersity or PDI is used as a measure of molecular weight distribution and is defined as

$$DPI = \frac{\text{Molecular weight of the polymer (Mn)}}{\text{Molecular weight of the repeating unit (M0)}}$$

where:

- M_n = number-average molecular weight of the polymer
- M_0 = molecular weight of a single repeating unit (monomer unit)

Ex- Polyethylene (PE) has a repeating unit of $-CH_2-CH_2-$, M_0=28 g/mol, If a polyethylene sample has an average molecular weight of 280,000 g/mol

DP=280,000/28=10,000

This means each polymer chain contains ~10,000 repeating units.

In case of monodisperse system (natural polymers and synthetic polymers made by anionic polymerization), PDI= 1, Since, $\mathbf{M_n} = \mathbf{M_w}$; and for other cases, PDI >1 or Mw is used as a measure of molecular weight distribution and is defined as- $\mathbf{M_w} > \mathbf{M_n}$

Measurement of molecular Weight

There are various physical and chemical methods for measurement of molecular weight of polymers. The methods used for molecular weight determination of polymers are follows:

a) End-group analysis

b) Colligative property measurement (Osmometry)

c) Light Scattering

d) Ultracentrifugation

e) Viscometry

a) End-Group Analysis:

End-group analysis is a method used to determine the molecular weight and sometimes the structure of a polymer by identifying and quantifying the functional groups at the polymer chain ends. Since polymer chains are formed by linking monomer units, each chain has two end groups (or one in the case of cyclic polymers).

- The number of end groups is inversely proportional to the degree of polymerization (DP).
- By measuring the concentration of end groups, the average molecular weight (Mn) of the polymer can be calculated using:

M_n=Molecular weight of monomer unit×Number of monomer units/Number of polymer

Common methods include titration for acidic or basic end groups, IR spectroscopy to detect characteristic vibrations, and NMR spectroscopy to measure end-group signals relative to the main chain. End-group analysis is valuable for verifying polymer structure, understanding polymerization mechanisms, and estimating molecular weight.

b) Colligative property measurement (Osmometry)-

Osmometry is a technique used to determine the molecular weight of polymers based on colligative properties, which depend on the number of solute particles rather than their chemical nature. In osmometry, the osmotic pressure of a polymer solution is measured, which is related to the polymer concentration and its molecular weight through the van't Hoff equation:

$$\Pi = \frac{n}{V}RT = \frac{cRT}{M_n}$$

where Π is the osmotic pressure, ccc is the polymer concentration, R is the gas constant, T is the absolute temperature, and Mn is the number-average molecular weight. Osmometry is particularly useful for high molecular weight polymers, as their large size makes other methods like end-group

analysis less accurate. The technique can be performed using membrane osmometry (semi-permeable membranes) or vapour pressure osmometry (measuring lowering of vapor pressure).

c) Light Scattering-

Light scattering is used to determine the weight-average molecular weight (Mw) and size of polymers in solution. When a polymer solution is illuminated, polymer molecules scatter light, and the intensity of scattered light is proportional to polymer concentration and molecular weight. For static light scattering (SLS), the relationship is given by the Rayleigh equation:

$$Kc/R_\theta = \frac{1}{M_w} + 2A_2c$$

Where, $K = \frac{4\pi^2 n_0^2}{\lambda_0^4 N_A}\left(\frac{dn}{dc}\right)^2$ (optical constant), , c = polymer concentration, R_θ = excess Rayleigh ratio (scattered light intensity), M_w = weight-average molecular weight, A2= second virial coefficient, n = refractive index of the solvent, λ_0 = wavelength of light in vacuum, N_A = Avogadro's number, d_n/d_c = refractive index increment.

d) Ultracentrifugation

Ultracentrifugation is a fundamental technique in polymer characterization used to determine molecular weight, molecular weight distribution, and polymer conformation. The principle is based on the sedimentation of polymer molecules in a solution when subjected to a very high centrifugal field. Different polymer chains, depending on their molecular weights, sediment at different rates. This behaviour allows accurate determination of average molecular weights as well as the distribution profile of polymers.

Types of Ultracentrifugation

1. **Sedimentation Velocity Method**
   - Measures the rate of sedimentation of polymer molecules.
   - Provides data on molecular size, shape of molecules, and degree of polydispersity.

When a polymer solution is subjected to high centrifugal force:

The polymer molecules experience:

Centrifugal force

$$F_c = m\,\omega^2 r$$

Here,

- m = mass of the polymer molecule, ω = angular velocity of centrifuge (rad/s), r = distance from the center of rotation

The **net force** acting on a polymer molecule is:

$$F = m(1 - \bar{v}\rho)\omega^2 r$$

Where:

- $\bar{v}$ = partial specific volume of polymer
- ρ = density of solvent

$$m(1 - \bar{v}\rho)\omega^2 r = fv$$

This force is opposed by **frictional resistance**:

Sedimentation Coefficient (s)

Defined as the ratio of sedimentation velocity to centrifugal acceleration:

$$s = \frac{\overline{\vartheta}}{r\,\omega^2}$$

From balance of forces

$$s = \frac{M(1 - \overline{\vartheta}\rho)}{f\,N_A}$$

2. Sedimentation Equilibrium Method

Centrifugation continues until sedimentation (due to centrifugal force) is balanced by diffusion (due to concentration gradient). Used for the absolute determination of molecular weight without calibration.

At equilibrium, **sedimentation** (tends to concentrate polymer at bottom) is balanced by **diffusion** (tends to spread molecules evenly). The concentration distribution of polymer with radial distance is given by:

$$\ln \frac{c_r}{c_{r_0}} = \frac{M(1 - \bar{v}\rho)\,\omega^2(r^2 - r_0^2)}{2RT}$$

Where: c_r= polymer concentration at radial position r, c_{r0} = concentration at reference position, R = gas constant, T = absolute temperature

A plot of ln c_r against ($r^2 - r_0^2$) gives a straight line, and the slope directly provides the molecular weight of the polymer. Thus, the sedimentation velocity method gives information on sedimentation coefficient and shape, while the sedimentation equilibrium method yields an absolute and accurate determination of molecular weight without the need for calibration standards.

- Ultracentrifugation is a physical method for determining molecular weights and distributions of polymers in solution. Sedimentation velocity gives information on size/shape, while sedimentation equilibrium provides absolute molecular weight.

e) Viscometry

Viscometry is one of the most common and simple methods used for determining the molecular weight of polymers in solution. It is based on measuring the change in viscosity of a solvent when a polymer is dissolved in it. Since polymer molecules are large and occupy significant hydrodynamic volume in solution, they increase the viscosity. The extent of this increase is directly related to the molecular weight of the polymer.

Relative viscosity (η_r): $$\eta_r = \frac{t}{t_0}$$

where t = flow time of polymer solution, t_0 = flow time of pure solvent.

Specific viscosity (η_{sp}):

$$\eta_{sp} = \frac{\eta - \eta_0}{\eta_0} = \eta_r - 1 =$$

where η = viscosity of solution, η_0 = viscosity of solvent.

Reduced viscosity (η_{red})

$$\eta_{red} = \frac{\eta_{sp}}{c}$$

where c = concentration of polymer.

Inherent viscosity (η_{inh}):

$$\eta_{inh} = \frac{\boldsymbol{ln}\, \eta_r}{c}$$

Intrinsic viscosity ([η][\eta][η]):

$$[\eta] = \lim_{c \to 0} \frac{\eta_{sp}}{c} = \lim_{c \to 0} \frac{\ln \eta_r}{c}$$

It is obtained by extrapolating reduced/inherent viscosity to zero concentration.

Molecular Weight Determination (Mark–Houwink Equation)

The relationship between **intrinsic viscosity** and **polymer molecular weight** is given by:

$$[\eta] = KM^a$$

Where:

- [[η] = intrinsic viscosity
- M = molecular weight of polymer
- K,a = constants depending on polymer–solvent system and temperature

Viscometry relates solution viscosity to polymer concentration and provides the **viscosity average molecular weight** using the Mark–Houwink equation. It is simple, inexpensive, but less accurate than light scattering or ultracentrifugation.

Analysis and testing of polymers:

1. Chemical analysis of polymers- Chemical analysis of polymers is carried out to determine their composition, functional groups, and structure. Techniques such as elemental analysis reveal the percentage of C, H, N, O, and S in the polymer, while end-group analysis helps estimate molecular weight. Chemical degradation or hydrolysis can break down the polymer into monomers for identification, and solubility tests give insight into polarity, branching, and crosslinking. These methods provide a basic understanding of the polymer's chemical nature.

2. Spectroscopic Methods

Fourier Transform Infrared (FTIR) Spectroscopy: Identifies functional groups and detects chemical modifications or degradation.

NMR Spectroscopy: ^{1}H NMR: Gives information on hydrogen environment in polymer backbone and side groups. ^{13}C NMR: Provides backbone carbon environment, tacticity, and branching.

Raman Spectroscopy: Complementary to IR for studying molecular vibrations, crystallinity, and polymer orientation.

UV–Visible Spectroscopy: Useful for conjugated polymers like polythiophene or polyaniline.

3. X-ray Techniques

X-ray Diffraction (XRD): **X-ray Diffraction (XRD)** is particularly important for determining the degree of crystallinity, crystal lattice parameters, and the overall ordering within polymer chains. Crystalline polymers produce sharp diffraction peaks, while amorphous polymers give broad halos, making XRD a reliable method to distinguish between crystalline and amorphous phases.

4. Microscopy

Microscopy is an important tool to study the morphology and surface features of polymers.

- **Light Microscopy (or Optical Microscopy)** is used to study the morphology and crystalline features of polymers at the microscale. It helps in observing spherulites, phase separation, and birefringence in semi-crystalline polymers when used with polarized light. This technique is simple, non-destructive, and useful for examining polymer films, fibers, and thin sections.
- **Electron Microscopy** is a powerful technique for studying polymers at very high magnification and resolution. **Scanning Electron Microscopy (SEM)** provides detailed images of polymer surfaces, fracture patterns, and filler dispersion. **Transmission Electron Microscopy (TEM**), on the other hand, allows visualization of internal structures such as crystallites, lamellae, and phase-separated domains at the nanometer scale.
- Together, SEM and TEM offer complementary insights into the micro- and nano-structural features of polymers.

5. Thermal Analysis

Differential Scanning Calorimetry (DSC) measures heat flow in polymers during heating or cooling. It determines glass transition (Tg), melting point (Tm), crystallization (Tc), and degree of crystallinity, helping to understand thermal stability and phase transitions.

Thermogravimetric Analysis (TGA) measures the weight change of a polymer with temperature. It is used to study thermal stability, decomposition temperature, filler content, and degradation behavior.

Differential Thermal Analysis (DTA) measures the temperature difference between a polymer sample and a reference during heating. It identifies endothermic and exothermic transitions, such as melting, crystallization, and decomposition.

6. Physical Testing

Physical testing evaluates a polymer's strength, durability, and resistance to deformation under various loads, which is critical for design, quality control, and material selection. These tests provide insights into elasticity, toughness, hardness, fatigue resistance.

Tensile Test: Determines elastic modulus, yield strength, tensile strength, and elongation at break. Used for assessing ductility and load-bearing capacity.

Compression Test: Measures resistance to compressive forces, important for elastomers, foams, and structural plastics.

Impact Test: Assesses toughness and resistance to sudden loading using Izod or Charpy methods. Tear Resistance: Evaluates the ability of films or sheets to resist propagation of cuts or tears, crucial for packaging materials.

Fatigue Test: Determines durability under cyclic or repeated loading, important for long-term applications like automotive or structural polymers.

Hardness and Abrasion resistance Test: Determines of tough a polymer's surface is. Hardness measures resistance to scratches or dents, while abrasion resistance measures how well it withstands wear or friction. These properties are important for tires, coatings, flooring, and durable plastic parts.

1.Which property of a polymer is *least* influenced by its molecular weight?

a) Tensile strength

b) Toughness

c) Electrical conductivity

d) Impact strength

Ans: c) Electrical conductivity

2. Which average molecular weight is obtained from end-group analysis?

a) M_n

b) M_w

c) M_v

d) All of these

Ans: a) M_n

3. The broadness of molecular weight distribution in polymers is best studied using:

a) X-ray diffraction

b) Gel permeation chromatography (GPC)

c) IR spectroscopy

d) DSC

Ans: b) GPC

4. For most synthetic polymers, typical PDI values are:

a) 1.0–1.2

b) 1.5–5.0

c) 5–10

d) > 20

Ans: b) 1.5–5.0

5. Which molecular weight is most appropriate for correlating with colligative properties (osmotic pressure)?

a) M_n

b) M_w

c) M_v

d) All of these

Ans: a) M_n

6. If M_n = 25,000 and M_w = 75,000, then PDI =?

a) 0.33

b) 1

c) 2

d) 3

Ans: d) 3

7. In viscosity measurement, the slope of log[η] vs. logM plot gives:

a) M_v

b) PDI

c) Mark–Houwink exponent (a)

d) None

Ans: c) Mark–Houwink exponent (a)

8. Which statement is true about polydispersity index (PDI)?

a) Lower PDI → broader distribution

b) Higher PDI → narrower distribution

c) PDI = 1 for monodisperse polymers

d) PDI cannot be < 1

Ans: c and d

9. The ratio M_w/M_n is called:

a) Molecular distribution factor

b) Polydispersity index (PDI)

c) Viscosity factor

d) Average chain ratio

Ans: b) Polydispersity index

10. For an ideal monodisperse polymer sample, the PDI value is:

a) 0

b) 0.5

c) 1

d) > 1

Ans: c) 1

11. Which molecular weight average is usually measured by light scattering?

a) M_n

b) M_w

c) M_v

d) All of these

Ans: b) M_w

12. Viscosity average molecular weight (M_v) is obtained using which equation?

a) Arrhenius equation

b) Mark–Houwink equation

c) Stokes' law

d) Flory–Huggins equation

Ans: b) Mark–Houwink equation

13. Order of molecular weight averages is generally:

a) $M_n > M_w > M_v$

b) $M_w > M_v > M_n$

c) $M_v > M_w > M_n$

d) $M_n > M_v > M_w$

Ans: b) $M_w > M_v > M_n$

14. Which average molecular weight gives equal importance to all polymer molecules irrespective of their size?

a) M_n

b) M_w

c) M_v

d) None

Ans: a) M_n

15. Weight average molecular weight (M_w) is always:

a) Greater than M_n

b) Smaller than M_n

c) Equal to M_n

d) Independent of M_n

Ans: a) Greater than M_n

16. If M_n = 20,000 and M_w = 40,000, then the PDI =?

a) 0.5

b) 1.0

c) 2.0

d) 4.0

Ans: c) 2.0

17. Polydispersity index (PDI) is a measure of:

a) Polymer crystallinity

b) Molecular weight distribution

c) Polymer branching

d) Degree of polymerization

Ans: b) Molecular weight distribution

18. Which method is best suited to measure M_n (number average molecular weight)?

a) Light scattering

b) Osmotic pressure

c) Ultracentrifugation

d) Viscosity

Ans: b) Osmotic pressure

19. A polymer sample has M_w = 60,000 and M_n = 60,000. The polymer is:

a) Monodisperse

b) Polydisperse

c) Branched

d) Crosslinked

Ans: a) Monodisperse

20. Viscosity average molecular weight (M_v) lies:

a) Between M_n and M_w

b) Below M_n

c) Above M_w

d) Equal to M_w

Ans: a) Between M_n and M_w

21. Which technique directly gives molecular weight distribution of polymers?

a) Gel Permeation Chromatography (GPC)

b) IR spectroscopy

c) DSC

d) Osmotic method

Ans: a) GPC

22. The significance of higher molecular weight in polymers is:

a) Better tensile strength and toughness

b) Lower viscosity of melt

c) Poorer mechanical properties

d) No effect

Ans: a) Better tensile strength and toughness

23. End-group analysis is suitable for:

a) Very high molecular weight polymers

b) Low molecular weight polymers

c) Crosslinked polymers

d) All of these

Ans: b) Low molecular weight polymers

24. Viscosity method for molecular weight measurement is based on:

a) Stokes' law

b) Mark–Houwink equation

c) Arrhenius equation

d) Beer–Lambert law

Ans: b) Mark–Houwink equation

25. Which average molecular weight is determined by light scattering method?

a) M_n

b) M_w

c) M_v

d) PDI

Ans: b) M_w

26. Osmotic pressure method gives directly:

a) M_n

b) M_w

c) M_v

d) PDI

Ans: a) M_n

27. Ultracentrifugation method is used to study:

a) Molecular weight distribution

b) Polymer crystallinity

c) Thermal transitions

d) Chemical composition

Ans: a) Molecular weight distribution

28. Which method involves determining molecular weight by counting reactive end-groups?

a) End-group analysis

b) Osmotic pressure method

c) Light scattering

d) Ultracentrifugation

Ans: a) End-group analysis

29. The principle of osmotic pressure measurement is based on:

a) Colligative properties

b) Viscosity of solution

c) Light diffraction

d) Sedimentation velocity

Ans: a) Colligative properties

30. Sedimentation equilibrium method in ultracentrifugation gives:

a) M_n

b) M_w

c) Absolute molecular weight distribution

d) Viscosity

Ans: c) Absolute molecular weight distribution

31. Which method is *least* suitable for branched/crosslinked polymers?

a) Light scattering

b) Osmotic pressure

c) End-group analysis

d) Viscosity method

Ans: c) End-group analysis

32. UV–Vis spectroscopy is most useful for polymers with:

a) Saturated aliphatic chains

b) Aromatic or conjugated groups

c) Highly crystalline regions

d) Crosslinking density

Ans: b) Aromatic or conjugated groups

33. Which technique identifies additives and degradation products in polymers?

a) DSC

b) Chemical analysis

c) SEM

d) XRD

Ans: b) Chemical analysis

34. In FTIR, the absorption band near 1720 cm^{-1} indicates:

a) OH stretching

b) C=O stretching (carbonyl group)

c) C–H stretching

d) C=C stretching

Ans: b) C=O stretching

35. XRD can determine:

a) Crystallinity

b) Intermolecular spacing

c) Crystal structure (lattice parameters)

d) All of these

Ans: d) All of these

36. A broad peak in polymer XRD indicates:

a) High crystallinity

b) Amorphous region

c) High molecular weight

d) Low tacticity

Ans: b) Amorphous region

37. Sharp diffraction peaks in polymer XRD correspond to:

a) Amorphous regions

b) Crystalline regions

c) Low molecular weight

d) Chain ends

Ans: b) Crystalline regions

38. SEM (Scanning Electron Microscopy) gives:

a) Surface morphology

b) Internal structure

c) Chain length

d) Molecular weight

Ans: a) Surface morphology

39. TEM (Transmission Electron Microscopy) is used to observe:

a) Bulk morphology at nanoscale

b) Thermal properties

c) Additives in polymers

d) Tensile strength

Ans: a) Bulk morphology at nanoscale

40. Optical microscopy is useful for studying:

a) Large-scale morphology (spherulites, phase separation)

b) Chain conformations

c) Crystallinity

d) End-groups

Ans: a) Large-scale morphology (spherulites, phase separation)

41. Atomic Force Microscopy (AFM) provides information on:

a) Thermal degradation

b) Surface topography at nanometre scale

c) Crystallinity index

d) Viscosity of solution

Ans: b) Surface topography at nanometre scale

42. Chemical analysis of polymers is used for:

a) Identifying additives

b) Checking degradation

c) Determining composition

d) All of these

Ans: d) All of these

43. Which spectroscopy is most suitable for identifying functional groups in polymers?

a) IR spectroscopy

b) NMR spectroscopy

c) UV–Vis spectroscopy

d) Mass spectroscopy

Ans: a) IR spectroscopy

44. Which technique is best for determining polymer tacticity and microstructure?

a) IR spectroscopy

b) NMR spectroscopy

c) X-ray diffraction

d) Microscopy

Ans: b) NMR spectroscopy

45. X-ray diffraction (XRD) is mainly used to study:

a) Chemical structure

b) Crystallinity and chain packing

c) Thermal stability

d) Optical properties

Ans: b) Crystallinity and chain packing

46. Scanning electron microscopy (SEM) is used to examine:

a) Molecular weight

b) Surface morphology

c) Crystallinity

d) Tacticity

Ans: b) Surface morphology

47. DSC thermogram of semi-crystalline polymers shows:

a) Only T_g

b) T_g + T_m + crystallization peaks

c) Weight loss steps

d) Stress relaxation curve

Ans: b) T_g + T_m + crystallization peaks

48. Polymers with higher molecular weight generally show:

a) Lower tensile strength

b) Higher tensile strength

c) Same tensile strength

d) No correlation

Ans: b) Higher tensile strength

49. High tear resistance is desirable in:

a) Fiberglass composites

b) Films and elastomers

c) Conducting polymers

d) Crystalline thermoplastics

Ans: b) Films and elastomers

50. Abrasion resistance is particularly important for polymers used in:

a) Coatings and tires

b) Optical lenses

c) Electrical insulation

d) Food packaging

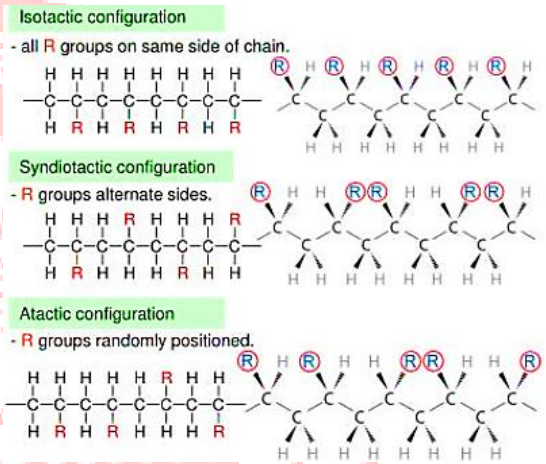
Ans: a) Coatings and tires

Unit – III

Polyethylene is the simplest linear chain. By replacing one H atom with a side-group or radical R→ a vinyl group of polymers Example: R=Cl (Polyvinyl chloride) or R=CH_3 (polypropylene)

R gives asymmetry to the repeating units that causes more than one way in which they can be linked to form a chain – stereoisomerism. Transformation from one in to the other isomer is not possible by bond rotation.

- Isotactic configuration: all R-groups are situated on the same side of the chain
- Syndiotactic configuration: R-groups are situated on alternate sides of the chain
- tactic configuration: R-groups are arranged in a random position



Crystal structures of polymers

Polymers can exist in crystalline, amorphous, or semi-crystalline states. Unlike small molecules, polymers rarely crystallize completely because of their long chains, entanglements, and irregularities. Instead, they form semi-crystalline structures where crystalline regions are dispersed within amorphous regions.

Polymers crystallize when their chains can pack in a regular, ordered way. This is favored by chain symmetry, stereoregularity (isotactic or syndiotactic structures), and strong intermolecular forces such as van der Waals interactions or hydrogen bonding. Atactic polymers, with random side groups, usually remain amorphous.

Polymers do not form large, perfect crystals like salts/metals. Instead, they form microscopic crystals known as **lamellae**, which further organize into **spherulites**.

Polymer	Crystal Structure / Unit Cell	Features
Polyethylene (PE)	Orthorhombic (normal pressure) Hexagonal (high pressure)	Chains packed in parallel; high symmetry allows good crystallization
Polytetrafluoroethylene (PTFE)	Hexagonal	Symmetric C–F bonds favour regular packing
Polypropylene (PP)	Monoclinic / Orthorhombic (isotactic) Amorphous (atactic)	Isotactic PP crystallizes; atactic PP cannot crystallize
Nylons (e.g., Nylon-6, Nylon-6,6)	Hydrogen-bonded crystals	Crystallization due to strong –NH···C=O hydrogen bonding
Polyethylene terephthalate (PET)	π–π stacked crystals	Crystallization via aromatic ring stacking + van der Waals interactions

Factors Affecting Crystallinity & Crystal Structure

- The crystallinity and crystal structure of polymers are influenced by several factors. Tacticity plays a key role: isotactic and syndiotactic polymers can crystallize effectively, while atactic polymers remain mostly amorphous.
- Chain branching disrupts regular packing, reducing crystallinity, which is why low-density polyethylene (LDPE) is less crystalline than high-density polyethylene (HDPE).
- Side groups also affect packing; bulky substituents hinder close chain alignment, making polymers like polystyrene largely amorphous.
- Intermolecular forces, such as hydrogen bonding in nylons or PET, promote tighter packing and higher crystallinity. Finally, the cooling rate during solidification matters: slow cooling favors well-formed crystals, whereas rapid quenching leads to amorphous, glassy structures.

Morphology of crystalline polymers

The morphology of a crystallizable polymer is a description of the forms that result from crystallization and the aggregation of crystallites. Crystalline polymers consist of a mixture of ordered crystalline regions and disordered amorphous regions, making them semi-crystalline.

The basic crystalline units are **lamellae**, thin plate-like structures formed by folded polymer chains, which rarely extend fully. Lamellae can grow radially from nucleation points to form **spherulites**, spherical aggregates visible under a polarized light microscope due to birefringence.

The morphology is influenced by chain regularity, molecular weight, cooling rate, additives, and strain. In some polymers like natural rubber, strain-induced crystallization aligns chains under tension, enhancing strength and elasticity. This combination of crystalline and amorphous regions gives semi-crystalline polymers a unique balance of rigidity, toughness, and flexibility.

Crystallization and Melting of Polymers

- Polymers can form semi-crystalline structures, where ordered crystalline regions (lamellae) coexist with amorphous regions. Crystallization occurs when polymer chains arrange into regular, ordered structures during cooling from the melt or from solution.
- The extent and quality of crystallization depend on chain regularity, tacticity, symmetry, molecular weight, chain flexibility, steric hindrance, and cooling rate. Slow cooling promotes well-formed crystals, whereas rapid quenching tends to produce mostly amorphous, glassy structures.
- The crystalline melting point (T_m) is the temperature at which these ordered crystalline regions gain sufficient thermal energy to overcome intermolecular forces and transform into a disordered melt. Tm is a first-order transition and is influenced by chain length, chain flexibility, side groups, intermolecular interactions, and crystallinity.
- Thermodynamically, melting is characterized by the heat of fusion (ΔH_f), which measures the energy required to break the crystalline interactions, and the entropy of fusion (ΔS_f), representing the increase in disorder during melting. The crystalline melting point can be approximated by $T_m \approx \Delta H_f / \Delta S_f$.
- The polymer structure and physical properties, including chain regularity, flexibility, and steric factors, directly determine the ability to crystallize and the resulting T_m, which in turn affects mechanical strength, thermal stability, and processability.

Melting Points of Homogeneous Polymer Series

In a homologous polymer series (polymers with the same repeating unit but varying chain length, e.g., polyethylene, $–(CH_2–CH_2)_n–$), the crystalline melting point (T_m) generally increases with increasing chain length. Longer chains have:

- Stronger van der Waals interactions between chains, which stabilize the crystalline regions.
- Better chain packing, allowing formation of more ordered lamellae and spherulites.

Effect of Chain Flexibility and Steric Factors

- **Chain Flexibility:** Flexible polymer chains can easily bend and fold, which often leads to less efficient packing in the crystalline regions, resulting in a lower crystalline melting point (T_m). Rigid chains or linear backbones allow tighter packing and therefore higher Tm.
- **Steric Factors / Side Groups:** Bulky or irregular side groups hinder close chain packing, reducing crystallinity and lowering Tm. For example, atactic polymers or polymers with large substituents (like polystyrene) are mostly amorphous.

The glass transition temperature (T_g)

The glass transition temperature ($\mathbf{T_g}$) is the temperature at which an amorphous polymer, or the amorphous regions of a semi-crystalline polymer, changes from a hard and brittle "glassy" state into a soft and flexible "rubbery" state.

The glass transition temperature ($\mathbf{T_g}$) depends on how easily polymer chains can move. Flexible chains and small side groups lower $\mathbf{T_g}$, while stiff backbones, bulky groups, strong intermolecular forces, and crosslinking raise it. Plasticizers lower $\mathbf{T_g}$, and in copolymers, $\mathbf{T_g}$ usually falls between the values of the individual polymers.

Glass transition temperature and molecular weight

The glass transition temperature of a polymer is influenced by its molecular weight, at least up to around a value of 20000. The relationship between glass transition temperature ($\mathbf{T_g}$) and molecular weight (M) can be expressed mathematically,

$$T_g = T_{g,\infty} - \frac{K}{M_n}$$

Where:

- $\mathbf{T_g}$ = glass transition temperature of the polymer with number-average molecular weight Mn
- $T_{g,\infty}$ = glass transition temperature at infinite molecular weight
- K = polymer-specific constant (depends on chain flexibility, structure, etc.)
- M_n = number-average molecular weight

Glass transition temperature and melting point:

The relationship between glass transition temperature ($\mathbf{T_g}$) and melting temperature ($\mathbf{T_m}$) in polymers is primarily about the different regions of the polymer they correspond to and how they change with molecular weight:

$$\boldsymbol{T_g = \frac{1}{2} T_m} \textbf{ (for symmetrical polymers)}$$

$$\boldsymbol{T_g = \frac{2}{3} T_m} \textbf{(for unsymmetrical polymers)}$$

1. Chain Topology

The **topology of polymer chains**—whether linear, branched, or crosslinked—strongly influences their properties and applications.

- **Linear polymers** can pack closely, resulting in high density, crystallinity, and tensile strength, as seen in HDPE.
- **Branched polymers** have side chains that disrupt packing, lowering crystallinity and density while increasing flexibility and impact resistance, such as in LDPE.
- **Crosslinked polymers** form a network structure through covalent bonds between chains, which restricts mobility and enhances strength, elasticity, thermal stability, and chemical resistance; examples include vulcanized rubber and epoxy resins.

The degree of branching and crosslinking is tailored to meet specific **property requirements**, such as flexibility, toughness, high strength, elasticity, thermal resistance, or transparency. Accordingly, polymer utilization depends on these structure-property relationships: branched polymers are widely used in films and flexible packaging, linear crystalline polymers in fibers and textiles, crosslinked elastomers in rubbers, and highly crosslinked thermosets in adhesives and heat-resistant components.

Property Requirements: Depending on the application, polymers are designed for:

Property	**Desired Chain Structure**	**Examples**
Flexibility & toughness	Branched, lightly crosslinked	LDPE, silicone rubber
High strength & crystallinity	Linear, high molecular weight	HDPE, nylon
Thermal & chemical resistance	Highly crosslinked	Epoxy, phenolics, vulcanized rubber
Elasticity	Low crosslink density	Natural rubber, polyurethane elastomers
Transparency	Amorphous, low crystallinity	PMMA, PC

Polymer Utilization

Application	Polymer Examples	Structure/Property Basis
Films & Packaging	LDPE, HDPE, PP	Branched or linear chains for flexibility and strength
Fibers & Textiles	Nylon, Polyester	Linear, crystalline chains for high tensile strength
Rubbers & Elastomers	Natural Rubber, EPDM	Crosslinked for elasticity and resilience
Thermosets & Adhesives	Epoxy, Phenolic Resins	Highly crosslinked for rigidity, thermal and chemical resistance
Transparent Components	PMMA, Polycarbonate	Amorphous, low crystallinity for clarity and transparency

1. Which configuration generally favors crystallinity in polymers?

a) Isotactic

b) Syndiotactic

c) Atactic

d) Both a & b

Ans: d) Both a & b

2. Atactic polymers are usually:

a) Highly crystalline

b) Amorphous

c) Semi-crystalline

d) Cross-linked

Ans: b) Amorphous

3. Tacticity refers to the arrangement of:

a) Main chain atoms

b) Side groups along the chain

c) Cross-linking sites

d) Crystalline lamellae

Ans: b) Side groups along the chain

4. The polymer chain configuration of natural rubber is:

a) Isotactic

b) Syndiotactic

c) Atactic

d) Cis-1,4 configuration

Ans: d) Cis-1,4 configuration

5. Which of the following polymers shows hydrogen bonding–stabilized crystalline structure?

a) Polyethylene

b) Nylon-6

c) Polystyrene

d) Polypropylene

Ans: b) Nylon-6

6. The crystalline regions in polymers are composed of folded chains known as:

a) Spherulites

b) Lamellae

c) Micelles

d) Crystallites

Ans: b) Lamellae

7. The higher the symmetry of the repeating unit in a polymer chain, the:

a) Lower the crystallinity

b) Higher the crystallinity

c) No effect on crystallinity

d) Causes amorphous structure

Ans: b) Higher the crystallinity

8. Which factor reduces crystallinity in polymers?

a) Linear chain structure

b) Regular tacticity

c) Branching

d) Chain symmetry

Ans: c) Branching

9. Bulky side groups such as phenyl ($–C_6H_5$) in polystyrene result in:

a) High crystallinity

b) Amorphous structure

c) Faster crystallization

d) Orthorhombic unit cell

Ans: b) Amorphous structure

10. Copolymerization usually leads to:

a) Increase in crystallinity

b) Decrease in crystallinity

c) No effect on crystallinity

d) Increase in chain symmetry

Ans: b) Decrease in crystallinity

11. Which of the following improves crystallization in polymers?

a) High cooling rate

b) Regular stereoregularity (tacticity)

c) Bulky side groups

d) Random copolymerization

Ans: b) Regular stereoregularity (tacticity)

12. The degree of crystallinity in polymers is generally measured using:

a) DSC

b) X-ray diffraction

c) Density measurement

d) All of the above

Ans: d) All of the above

13.Syndiotactic polymers show alternating placement of substituents on:

a) Same side of the chain

b) Opposite sides of the chain

c) Random sides of the chain

d) None of the above

Ans: b) Opposite sides of the chain

14. Crystalline regions in polymers are stabilized mainly by:

a) Hydrogen bonding

b) Van der Waals forces

c) Ionic bonding

d) Metallic bonding

Ans: b) Van der Waals forces

15. The crystal structure most common in polyethylene is:

a) Orthorhombic

b) Hexagonal

c) Cubic

d) Triclinic

Ans: a) Orthorhombic

16. The folded chain lamellae structure in crystalline polymers is observed in:

a) Melt crystallization

b) Solution crystallization

c) Strain-induced crystallization

d) All of the above

Ans: d) All of the above

17. Spherulites in polymers are observed under:

a) SEM

b) TEM

c) Polarized optical microscopy

d) XRD

Ans: c) Polarized optical microscopy

18. The crystalline melting point (T_m) is primarily determined by:

a) Chain flexibility and packing

b) Degree of branching

c) Intermolecular forces

d) All of the above

Ans: d) All of the above

19. For a homologous polymer series, T_m generally:

a) Increases with chain length

b) Decreases with chain length

c) Remains constant

d) First increases then decreases

Ans: a) Increases with chain length

20. Glass transition temperature (T_g) is associated with:

a) Crystalline melting

b) Segmental motion of chains

c) Primary bond breaking

d) Decomposition

Ans: b) Segmental motion of chains

21. For most polymers, the approximate ratio of T_g to T_m is:

a) 0.1

b) 0.5

c) 0.75

d) 1.0

Ans: b) 0.5

22. Increase in chain branching generally causes T_g to:

a) Increase

b) Decrease

c) Remain constant

d) Become unpredictable

Ans: b) Decrease

23. Cross-linking in polymers generally leads to:

a) Increase in T_g

b) Decrease in T_g

c) Decrease in T_m

d) No effect

Ans: a) Increase in T_g

24. The entropy of fusion (ΔS_f) is generally:

a) Larger for flexible chains

b) Larger for rigid chains

c) Independent of chain type

d) Negative

Ans: a) Larger for flexible chains

25. Plasticizers lower T_g by:

a) Increasing free volume

b) Enhancing crystallinity

c) Strengthening intermolecular forces

d) Cross-linking chains

Ans: a) Increasing free volume

26. A polymer for high-temperature applications should have:

a) High T_g and T_m

b) Low T_g and high T_m

c) Low T_g and T_m

d) High crystallinity but low T_g

Ans: a) High T_g and T_m

27. Polyethylene terephthalate (PET) has good mechanical properties mainly due to:

a) Hydrogen bonding

b) Aromatic ring stiffness

c) Cross-linking

d) High tacticity

Ans: b) Aromatic ring stiffness

28. The degree of crystallinity in polymers is usually measured by:

a) DSC (Differential Scanning Calorimetry)

b) X-ray diffraction

c) Density measurements

d) All of the above

Ans: d) All of the above

29. Which factor reduces the crystallinity of polymers?

a) Linear chains

b) High tacticity

c) Branching and bulky side groups

d) Slow cooling

Ans: c) Branching and bulky side groups

30. Which polymer shows strain-induced crystallization?

a) Polyethylene

b) Polystyrene

c) Natural rubber

d) PVC

Ans: c) Natural rubber

31. Glass transition temperature (T_g) is:

a) A first-order transition

b) A second-order transition

c) A decomposition temperature

d) Equal to T_m

Ans: b) A second-order transition

32. Which of the following polymers is highly crystalline?

a) Polystyrene

b) Polyethylene

c) Polyisoprene

d) Polyvinyl chloride

Ans: b) Polyethylene

33. Which type of crystallization occurs when polymers are stretched?

a) Melt crystallization

b) Solution crystallization

c) Strain-induced crystallization

d) Quench crystallization

Ans: c) Strain-induced crystallization

34. Which factor most strongly influences the glass transition temperature (T_g)?

a) Chain flexibility

b) Degree of crystallinity

c) Molar mass

d) Cooling rate

Ans: a) Chain flexibility

35. Which of the following groups increases T_g due to restricted chain motion?

a) $–CH_3$

b) $–C_6H_5$ (phenyl group)

c) –H

d) –Cl

Ans: b) $–C_6H_5$ (phenyl group)

36. Which polymer shows a very high T_g due to rigid structure?

a) Polyethylene

b) Polystyrene

c) Polycarbonate

d) PTFE

Ans: c) Polycarbonate

37. Which technique is best for determining T_g of a polymer?

a) X-ray diffraction

b) Differential scanning calorimetry (DSC)

c) TEM

d) FTIR spectroscopy

Ans: b) Differential scanning calorimetry (DSC)

38. The heat of fusion (ΔH_f) of a polymer decreases when:

a) Crystallinity increases

b) Crystallinity decreases

c) Molecular weight increases

d) Cooling rate is slow

Ans: b) Crystallinity decreases

39. Which of the following increases T_m?

a) Branching

b) Cross-linking

c) Bulky side groups

d) Random copolymerization

Ans: b) Cross-linking

40. Which of the following polymers has both crystalline and amorphous regions?

a) Thermosets

b) Elastomers

c) Semi-crystalline polymers

d) Atactic polymers

Ans: c) Semi-crystalline polymers

41. Glass transition temperature (T_g) can be lowered by:

a) Addition of plasticizers

b) Increasing cross-linking

c) Introducing rigid groups

d) Increasing crystallinity

Ans: a) Addition of plasticizers

42. Which factor does *not* affect crystallization in polymers?

a) Tacticity

b) Chain branching

c) Cooling rate

d) Color of polymer

Ans: d) Color of polymer

43. T_m of a polymer corresponds to:

a) Complete loss of crystalline order

b) Glass transition

c) Bond breaking

d) Thermal decomposition

Ans: a) Complete loss of crystalline order

44. Glass transition temperature (T_g) is the temperature where polymer changes from:

a) Crystalline solid → liquid

b) Brittle glassy state → rubbery state

c) Amorphous solid → crystalline solid

d) Liquid → crystalline solid

Ans: b) Brittle glassy state → rubbery state

45. Which polymer property is directly related to crystallinity?

a) Transparency

b) Density

c) Color

d) Optical birefringence

Ans: b) Density

46. Highly crystalline polymers usually have:

a) High strength, high density, opaque appearance

b) Low strength, low density, transparent appearance

c) Low Tm, high transparency

d) High elasticity

Ans: a) High strength, high density, opaque appearance

47. Which relationship is most correct for most polymers?

a) $T_g > T_m$

b) $T_g \approx T_m$

c) $T_g < T_m$

d) $T_g = 0.5\ T_m$ (approximately)

Ans: c) $T_g < T_m$

49. Semi-crystalline polymers exhibit:

a) Only crystalline morphology

b) Only amorphous morphology

c) Both crystalline lamellae and amorphous regions

d) Completely isotropic morphology

Ans: c) Both crystalline lamellae and amorphous regions

50. The crystallinity of a polymer increases when:

a) Chains are regular and symmetric

b) Bulky side groups are present

c) Cooling rate is very fast

d) Random copolymerization occurs

Ans: a) Chains are regular and symmetric

51. Which factor favors a higher crystalline melting point?

a) Regular chain symmetry

b) Strong intermolecular forces

c) High molecular weight

d) All of the above

Ans: d) All of the above

52. Which type of tacticity leads to higher T_m?

a) Atactic

b) Isotactic

c) Random

d) Cross-linked

Ans: b) Isotactic

53. For a polymer, the crystalline melting point (T_m) is proportional to:

a) $\Delta H_f / \Delta S_f$

b) $\Delta S_f / \Delta H_f$

c) $T_g \times \Delta H_f$

d) $\Delta H_f \times$ molecular weight

Ans: a) $\Delta H_f / \Delta S_f$

54. Which factor reduces the physical strength of a polymer?

a) High intermolecular forces

b) High degree of polymerization

c) High branching

d) Cross-linking

Ans: c) High branching

55. Nylon and polyesters have high strength due to:

a) Cross-linking

b) Hydrogen bonding and strong intermolecular forces

c) Low crystallinity

d) Random chain orientation

Ans: b) Hydrogen bonding and strong intermolecular forces

Unit - IV

Polymer processing is the method of converting raw polymers into useful products such as plastics, elastomers, and fibers.

Plastics, elastomers and fibres

Plastics: Plastics can be thermoplastics or thermosets and are processed using techniques like injection molding, extrusion, blow molding, and compression molding to make items such as bottles, sheets, pipes, and automotive parts.

Elastomers: Elastomers or rubbery polymers, are processed by mastication to soften the material, mixing with fillers and curing agents, shaping through extrusion or molding, and vulcanization to improve elasticity, strength, and durability; they are used in tires, seals, and gaskets.

Fibres: Fibres are long, thread-like polymers used in textiles and reinforcement materials and are produced by melt spinning or solution spinning, followed by drawing to align polymer chains and increase strength. Overall, polymer processing allows raw polymers to be transformed into products with the desired shape, strength, and flexibility for practical applications.

Compounding

- Compounding is the process of mixing a base polymer with additives, fillers, and other materials to improve its properties or make it suitable for specific applications.
- This process enhances mechanical strength, flexibility, thermal stability, flame resistance, chemical resistance, and appearance.
- Common additives include fillers like talc and glass fibers to increase strength, plasticizers to improve flexibility, stabilizers to protect against heat or UV degradation, flame retardants to reduce flammability, and colorants for desired shades.
- The polymer and additives are uniformly mixed using equipment such as internal mixers, extruders, or two-roll mills. After compounding, the material is ready for shaping through extrusion, molding, or fiber spinning, and finds applications in automotive parts, cables, packaging, films, and consumer goods.

Calendering:

- A calendering machine is used to make thin, uniform sheets or films from rubber, plastics, or PVC.
- It works by feeding material through a series of rollers that compress and stretch it to the desired thickness. The finished sheet is then cooled and collected. Advantages: Good surface finish and uniform thickness.
- PVC, polyethylene, acrylonitrile-butadiene styrene copolymers (ABS) and rubbers are among the main polymers which are usually calendared into sheets.

Die Casting

- It is process by which liquid prepolymer is converted into a shape object of a desired shape**.**
- A metal casting process where molten metal is forced under high pressure into a mold cavity.
- To produce precise, high-volume metal parts with good surface finish. Automotive parts (engine blocks, gear housings), hardware, electronics casings. Polyesters, urethanes and epoxides etc. are suitable for die casting.

Rotational Casting (Rotocasting):

- Rotational casting is a manufacturing process used to create hollow or complex-shaped objects.
- In this method, a hollow mold is filled with a liquid material, typically plastic or low-melting-point metal, and then rotated slowly on two or more axes. As the mold rotates, the material spreads evenly along the inner walls and solidifies, forming a uniform, seamless part.
- This technique allows the production of large, lightweight, and durable items without joints or seams.

Film Casting:

- Film casting is a manufacturing process used to produce thin plastic or polymer films.

- In this method, molten polymer is spread or extruded onto a flat surface or through a slit die to form a continuous sheet or film. The material is then cooled and solidified to achieve uniform thickness and smooth surface.
- Film casting is widely used for producing packaging materials, protective films, shrink wraps, and laminates, offering precise control over thickness and surface quality.

Moulding

Moulding is a manufacturing process in which a material, such as plastic, rubber, or metal, is shaped by being placed into a mold and allowed to solidify. It includes different techniques depending on the desired shape and application:

- **Injection Moulding:** Molten material is injected into a mold under high pressure to produce precise, complex parts.
- **Blow Moulding:** Air is used to inflate molten plastic inside a mold to create hollow objects like bottles and containers. Thermoplastic materials such as polyethene, PVC, polystyrene, nylon, polypropylene etc can be blow moulded.
- **Extrusion Moulding:** Material is forced through a shaped die to produce continuous profiles like pipes, rods, or sheets. It is also used for coating wires and cables with PVC or rubber.

Thermoforming

Thermoforming is a very useful process for fabrication three dimensional articles from plastic sheets. The thermoplastic sheet is heated to its softening temperature.

Foaming

- Foaming introduces gas bubbles into a material (plastic, rubber, or metal) to create a lightweight, porous structure.
- This reduces density and provides cushioning or insulation. Applications include foam mattresses, packaging materials, insulation panels, and lightweight structural components.

Reinforcing

- Reinforcing involves adding fibres or fillers to a material to increase its strength, stiffness, and durability.
- Commonly used in composites, it improves mechanical properties without significantly increasing weight.
- Applications include carbon fibre or glass fibre reinforced plastics, reinforced concrete, and automotive parts.

Fibre spinning

Spinning is the process by which fibres are made from the polymers. There are three methods of spinning.

- **Melt spinning** is a fibres manufacturing process in which a polymer is first melted and then extruded through tiny holes called spinnerets into cool air or water, where it solidifies into continuous fibers. This method is commonly used for thermoplastic polymers such as polyester, nylon, and polypropylene.
- **Wet spinning** is a fibres production process in which the polymer is first dissolved in a solvent to form a solution, which is then extruded through spinnerets into a coagulating bath where the fibers solidify. This method is commonly used for fibers such as rayon, acrylic, and other specialty fibers.
- **Dry spinning** is a fibres production process in which a polymer solution is extruded into warm air, causing the solvent to evaporate and leaving behind solid fibers. This method is commonly used for fibers such as acetate, spandex, and some acrylics. Dry spinning is advantageous because it is faster than wet spinning and works well with volatile solvents.

1. Which of the following is a natural fibre?
   a) Nylon
   b) Silk
   c) PVC
   d) Teflon
   Ans: b) Silk

2. Which of these is an elastomer?
   a) Polyethylene
   b) Neoprene
   c) Polystyrene
   d) Teflon
   Ans: b) Neoprene

3. Which of the following is a thermosetting plastic?
   a) PVC
   b) Bakelite
   c) Polypropylene
   d) Nylon
   Ans: b) Bakelite

4. The strength of fibres is mainly due to:
   a) Random orientation
   b) Crosslinking
   c) Molecular orientation along fibre axis
   d) Plasticizers
   Ans: c) Molecular orientation along fibre axis

5. The process of mixing stabilizers, fillers, and plasticizers into raw polymer is called:
   a) Vulcanization
   b) Compounding
   c) Curing

d) Extrusion

Ans: b) Compounding

6. Plasticizers are added to polymers to:

a) Increase hardness

b) Improve flexibility

c) Increase density

d) Reduce ductility

Ans: b) Improve flexibility

7. Calendering is mainly used to produce:

a) Hollow products

b) Sheets and films

c) Pipes

d) Fibres

Ans: b) Sheets and films

8. In die casting of polymers, shaping occurs in:

a) Vacuum chamber

b) Fixed mould under pressure

c) Rotating drum

d) Roller gap

Ans: b) Fixed mould under pressure

9. Rotational casting is best suited for:

a) Complex solid shapes

b) Hollow seamless products like tanks

c) Thin films

d) Tyres

Ans: b) Hollow seamless products like tanks

10. Film casting is used to make:

a) Bottles

b) Packaging films

c) Pipes

d) Laminates

Ans: b) Packaging films

11. Injection moulding is widely used for:

a) Continuous profiles

b) Complex 3D plastic components

c) Hollow containers

d) Fibre spinning

Ans: b) Complex 3D plastic components

12. In blow moulding, the precursor hollow tube is called:

a) Preform

b) Parison

c) Billet

d) Extrudate

Ans: b) Parison

13. Extrusion moulding is typically used for:

a) Plastic pipes and rods

b) Toys

c) Bottles

d) Sheets

Ans: a) Plastic pipes and rods

14. Thermoforming involves:

a) Pouring molten polymer into moulds

b) Heating sheets and forming them by pressure/vacuum

c) Compressing powders in a die

d) Rotating a mould with melt

Ans: b) Heating sheets and forming them by pressure/vacuum

15. Foamed plastics are produced by:
    a) Crosslinking
    b) Introducing gas/foaming agents
    c) Stretching fibres
    d) Vulcanization
    Ans: b) Introducing gas/foaming agents

16. The addition of glass fibres to polymers improves:
    a) Flexibility
    b) Mechanical strength and stiffness
    c) Transparency
    d) Brittleness
    Ans: b) Mechanical strength and stiffness

17. Nylon fibres are generally produced by:
    a) Wet spinning
    b) Dry spinning
    c) Melt spinning
    d) Gel spinning
    Ans: c) Melt spinning

18. Rayon fibres are manufactured by:
    a) Melt spinning
    b) Wet spinning
    c) Dry spinning
    d) Electrospinning
    Ans: b) Wet spinning

19. Dry spinning involves:
    a) Polymer melt extruded into water
    b) Polymer solution extruded and solvent evaporates
    c) Polymer extruded under vacuum

d) Polymer compressed and cooled

Ans: b) Polymer solution extruded and solvent evaporates

20. Spinnerets are used in:

a) Blow moulding

b) Fibre spinning

c) Calendering

d) Extrusion only

Ans: b) Fibre spinning

21. Which of the following is used as a foaming agent?

a) Sulphur

b) Sodium bicarbonate

c) Urea

d) Benzene

Ans: b) Sodium bicarbonate

22. The main advantage of rotational moulding is:

a) High production rate

b) Ability to produce seamless hollow parts

c) Requires no cooling

d) Produces only thin films

Ans: b) Ability to produce seamless hollow parts

23. Extrusion moulding is unsuitable for:

a) Pipes

b) Rods

c) Complex hollow bottles

d) Profiles

Ans: c) Complex hollow bottles

24. Which of the following is a thermoplastic?

a) Epoxy resin

b) PVC

c) Bakelite

d) Urea-formaldehyde resin

Ans: b) PVC

25. In injection moulding, the function of the screw is to:

a) Provide cooling

b) Mix and melt the polymer

c) Compress the mould

d) Evaporate solvents

Ans: b) Mix and melt the polymer

26. The common plastic used in making carry bags is:

a) Polystyrene

b) Polyethylene

c) Bakelite

d) Nylon

Ans: b) Polyethylene

27. Die casting of polymers is preferred when:

a) Only hollow objects are needed

b) High dimensional accuracy is required

c) Low-cost products are needed

d) Fibres are required

Ans: b) High dimensional accuracy is required

28. Thermoforming is used in the production of:

a) Car tyres

b) Disposable plastic cups and trays

c) Glass fibres

d) Foam boards

Ans: b) Disposable plastic cups and trays

29. Which polymer is commonly used in making foamed products such as Styrofoam?
    a) Nylon
    b) Polystyrene
    c) PVC
    d) Polyester
    Ans: b) Polystyrene

30. Glass fibre reinforced plastic is also known as:
    a) PVC
    b) GRP (Glass Reinforced Plastic)
    c) Polycarbonate
    d) Teflon
    Ans: b) GRP (Glass Reinforced Plastic)

31. The strength of elastomers increases significantly after:
    a) Vulcanization
    b) Foaming
    c) Moulding
    d) Calendering
    Ans: a) Vulcanization

32. Fibre spinning process where polymer solution is passed into a coagulation bath is:
    a) Melt spinning
    b) Wet spinning
    c) Dry spinning
    d) Gel spinning
    Ans: b) Wet spinning

33. The foaming process reduces:
    a) Density of polymer
    b) Flexibility of polymer
    c) Toughness of polymer

d) Strength of polymer

Ans: a) Density of polymer

34. Polyethylene terephthalate (PET) fibres are produced by:

a) Wet spinning

b) Melt spinning

c) Dry spinning

d) Gel spinning

Ans: b) Melt spinning

35. The most common material used in making water tanks by rotational moulding is:

a) Polycarbonate

b) Polyethylene

c) Bakelite

d) Nylon

Ans: b) Polyethylene

36. Calendering is commonly used in the manufacture of:

a) Tyres

b) PVC sheets and films

c) Bottles

d) Nylon ropes

Ans: b) PVC sheets and films

37. Which process is most suitable for producing hollow plastic bottles?

a) Calendering

b) Extrusion

c) Blow moulding

d) Film casting

Ans: c) Blow moulding

38. The polymer used in bulletproof jackets (Kevlar) belongs to which category?

a) Polyolefins

b) Polyamides (Aramids)

c) Polyesters

d) Polyurethanes

Ans: b) Polyamides (Aramids)

39. The primary function of stabilizers in polymers is to:

a) Prevent degradation due to heat and light

b) Increase crystallinity

c) Improve fibre orientation

d) Reduce flexibility

Ans: a) Prevent degradation due to heat and light

40. In extrusion, the shape of the final product is determined by:

a) The mould cavity

b) The die opening

c) The cooling chamber

d) The roller gap

Ans: b) The die opening

41. Which of the following is a thermoset polymer?

a) Polypropylene

b) Bakelite

c) PVC

d) Teflon

Ans: b) Bakelite

42. Which of these processes is not suitable for thermosetting plastics?

a) Injection moulding

b) Compression moulding

c) Extrusion

d) Calendering

Ans: d) Calendering

43. The process used to form continuous lengths of materials like pipes and profiles is:
    a) Blow moulding
    b) Extrusion moulding
    c) Thermoforming
    d) Rotational moulding
    Ans: b) Extrusion moulding

44. The parison in blow moulding is:
    a) A mould cavity
    b) A tubular extrudate before blowing
    c) A spinneret opening
    d) A type of additive
    Ans: b) A tubular extrudate before blowing

45. The most important additive used in elastomers for durability is:
    a) Stabilizer
    b) Vulcanizing agent
    c) Plasticizer
    d) Colourant
    Ans: b) Vulcanizing agent

46. The fibre spinning method used for producing acrylic fibres is:
    a) Melt spinning
    b) Dry spinning
    c) Wet spinning
    d) Gel spinning
    Ans: b) Dry spinning

47. Film blowing is a modification of:
    a) Calendering
    b) Extrusion
    c) Rotational moulding

d) Injection moulding

Ans: b) Extrusion

48. The moulding technique used for manufacturing electrical switches is:

a) Blow moulding

b) Compression moulding

c) Calendering

d) Thermoforming

Ans: b) Compression moulding

49. Foamed polystyrene is popularly known as:

a) Styrofoam

b) Nylon foam

c) Bakelite foam

d) Polyester foam

Ans: a) Styrofoam

50. Fibre-reinforced plastics (FRP) are produced to:

a) Reduce polymer cost

b) Increase mechanical strength and stiffness

c) Make plastics biodegradable

d) Increase transparency

Ans: b) Increase mechanical strength and stiffness

51. The most suitable process for making large hollow tanks is:

a) Blow moulding

b) Rotational moulding

c) Injection moulding

d) Calendering

Ans: b) Rotational moulding

52. Which process is best for making disposable polystyrene cups?

a) Thermoforming

b) Injection moulding

c) Blow moulding

d) Extrusion

Ans: a) Thermoforming

53. PVC sheets are commonly produced by:

a) Calendering

b) Blow moulding

c) Injection moulding

d) Fibre spinning

Ans: a) Calendering

54. The main purpose of antioxidants in polymer compounding is:

a) Improve colour

b) Prevent oxidative degradation

c) Increase elasticity

d) Act as blowing agents

Ans: b) Prevent oxidative degradation

55. Which of the following polymers is classified as an elastomer?

a) Polystyrene

b) Buna-N

c) Polyethylene

d) Nylon-6

Ans: b) Buna-N

56. The moulding process where a heated polymer sheet is sucked onto a mould surface by vacuum is:

a) Blow moulding

b) Thermoforming

c) Injection moulding

d) Compression moulding

Ans: b) Thermoforming

57. The foaming technique is applied to polymers mainly to:

a) Reduce cost and weight

b) Increase crystallinity

c) Improve fibre orientation

d) Reduce flexibility

Ans: a) Reduce cost and weight

58. In wet spinning, fibres are formed by:

a) Cooling molten polymer

b) Evaporation of solvent

c) Polymer solution coagulating in a bath

d) Crosslinking in moulds

Ans: c) Polymer solution coagulating in a bath

59. Teflon is a polymer of:

a) Vinyl chloride

b) Tetrafluoroethylene

c) Styrene

d) Caprolactam

Ans: b) Tetrafluoroethylene

60. Which of the following processes is best for making high-volume identical plastic products with complex shapes?

a) Injection moulding

b) Extrusion

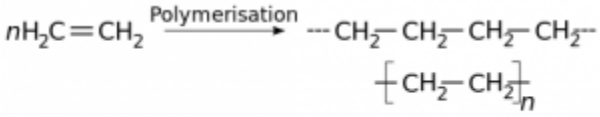
c) Rotational moulding

d) Calendering

Ans: a) Injection moulding

UNIT – V

1. Polythene: -Polyethene is obtained by the polymerisation of ethylene



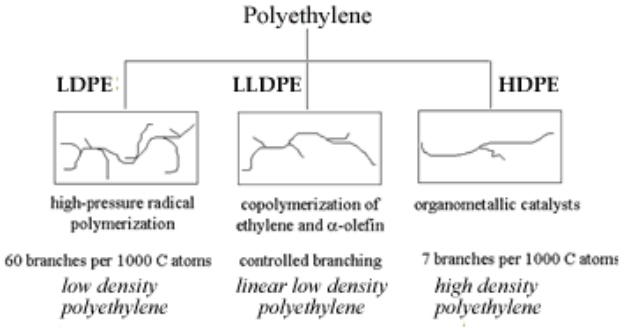
There are two types of polythene-

(i) Low density polythene:

- It is obtained by the polymerisation of Ethene under high pressure of 1000 to 2000 atmospheres at a temperature of 350 K to 570 K in the presence of traces of dioxygen or a peroxide initiator (catalyst).
- The low-density polythene (LDP) obtained through the free radical addition and H-atom abstraction has highly branched structure. It is chemically inert and tough but flexible and a poor conductor of electricity. Hence, it is used in the insulation of electricity carrying wires and manufacture of squeeze bottles, toys and flexible pipes.

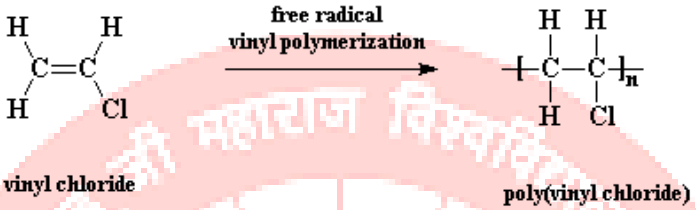
(ii) High density polythene:

- It is formed when addition polymerisation of Ethene takes place in a hydrocarbon solvent in the presence of a catalyst such as triethylaluminium and titanium tetrachloride (Ziegler-Natta catalyst) at a temperature of 333 K to 343 K and under a pressure of 6-7 atmospheres. It is also chemically inert and more tough and hard. It is used for manufacturing buckets, dustbins, bottles, pipes, etc.



Polyvinyl Chloride- PVC is a synthetic polymer made from the monomer vinyl chloride (CH_2=CHCl).

Vinyl chloride is usually produced from **ethylene** through the chlorination/oxychlorination process, producing ethylene dichloride (EDC, $ClCH_2$–CH_2Cl), which is then pyrolyzed to form vinyl chloride monomer (VCM).

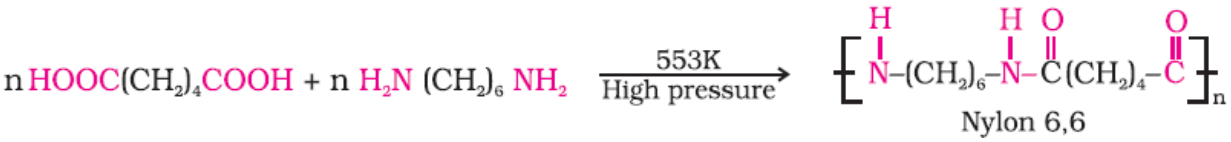


PVC is a type of plastic that we use in everyday life because it's strong, long-lasting, and flexible when needed. The hard form is used for things like water pipes, window frames, and electrical wiring covers, while the softer form is found in products like raincoats, flooring, medical tubes and toys. Because it can be made either rigid or flexible, PVC has become one of the most useful materials in construction, healthcare, and daily household items.

Polyamides- Polyamides are a class of polymers in which the repeating units (monomers) are linked together by amide bonds (–CONH–). They can be naturally occurring (like proteins, wool, and silk) or synthetic (like nylons and aramids).

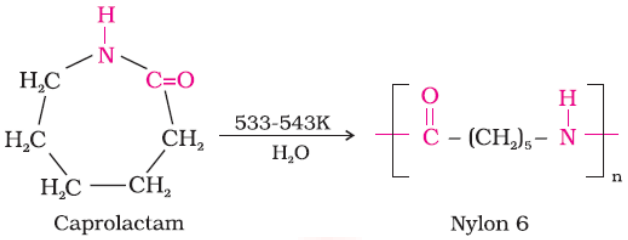
Preparation of Nylons

Nylon 6, 6: - It is prepared by the condensation polymerisation of hexamethylenediamine with adipic acid under high pressure and at high temperature. Nylon 6, 6 is used in making sheets, bristles for brushes and in textile industry.



adipic acid hexamethylenediamine Nylon 6, 6

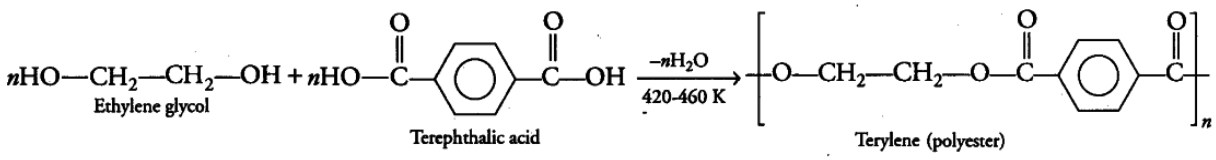
Nylon 6: -It is obtained by heating Caprolactam with water at a high temperature. Nylon 6 is used for the manufacture of tyre cords, fabrics and ropes.



Polyamides are used in textiles (clothes, ropes, carpets, parachutes), engineering plastics (gears, bearings, auto parts), and safety materials (Kevlar in bulletproof vests, Nomex in fireproof suits). They're strong, durable, and useful in both industry and daily life.

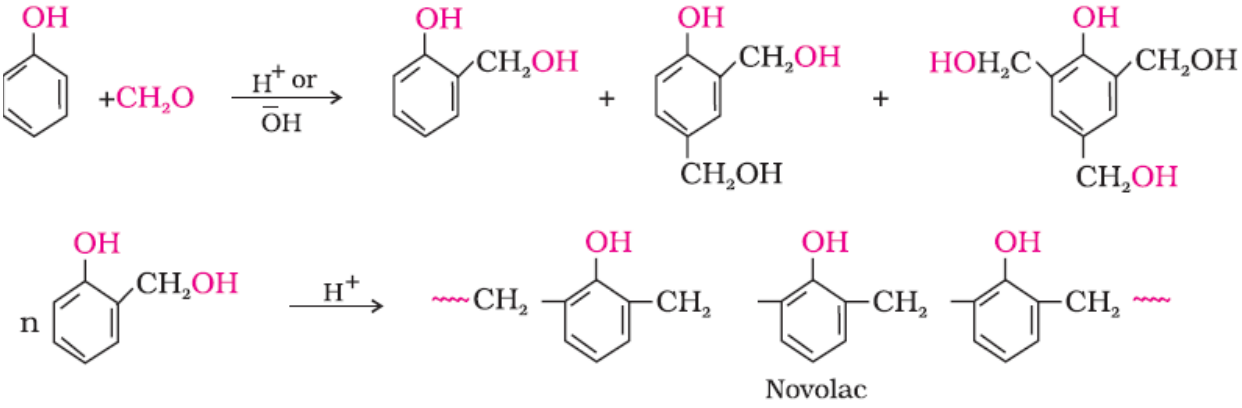
Polyesters- These are the poly condensation products of dicarboxylic acids and diols.

Dacron or Terylene is the best-known example of polyesters. It is manufactured by heating a mixture of ethylene glycol and terephthalic acid at 420 to 460 K in the presence of Zinc acetate antimony trioxide catalyst. Dacron fibre (Terylene) is crease resistant and is used in blending with cotton and wool fibres and also as glass reinforcing materials in safety helmets, etc.

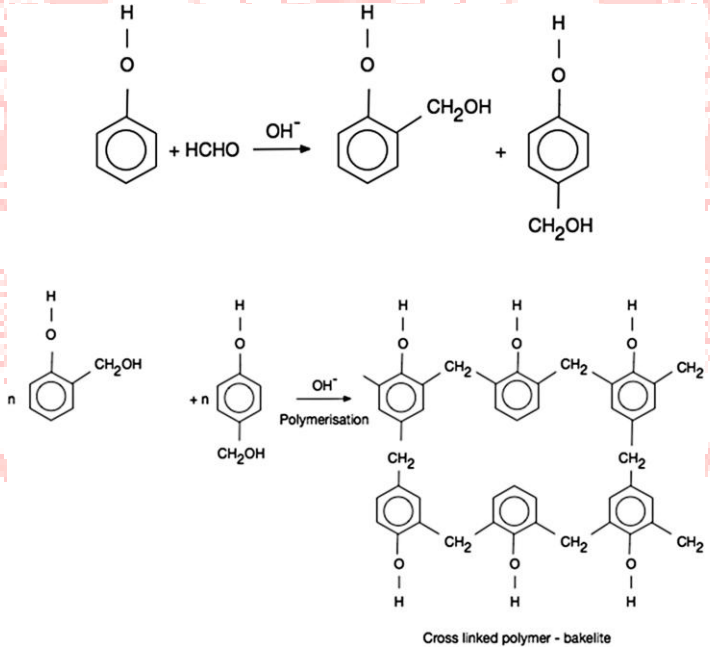


Phenol – formaldehyde polymer (Bakelite and related polymers): -

- Phenol - formaldehyde polymers are the oldest synthetic polymers. These are obtained by the condensation reaction of phenol with formaldehyde in the presence of either an acid or a base catalyst.
- The reaction starts with the initial formation of o-and/or p-hydroxymethylphenol derivatives, which further react with phenol to form compounds having rings joined to each other through $–CH_2$ group. The initial product could be a linear product – Novolac used in paints.

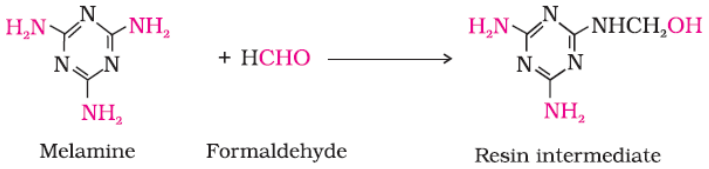


Novolac on heating with formaldehyde undergoes cross linking to form infusible solid mass called Bakelite. It is used for making combs, phonograph records, electrical switches and handles of various utensils.



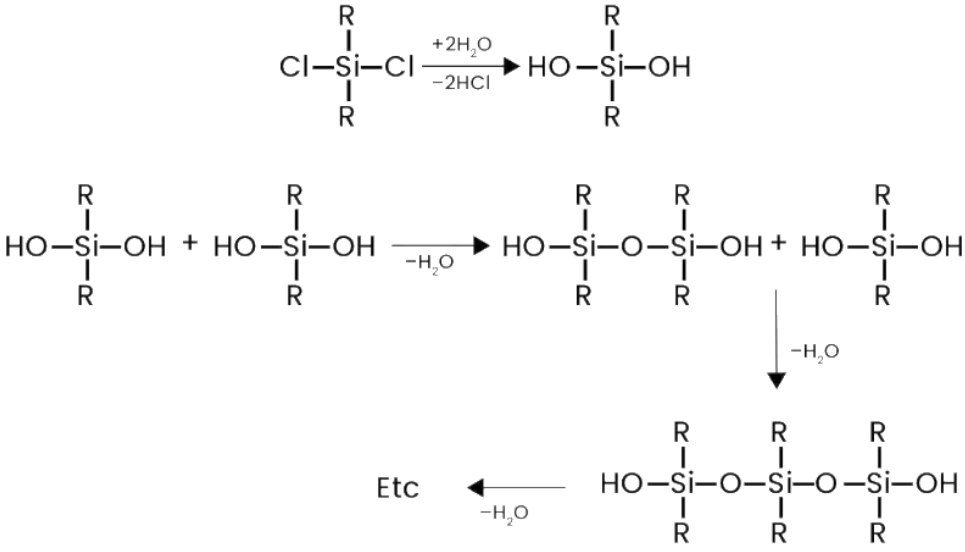
Melamine- formaldehyde Polymer:

Melamine formaldehyde polymer is formed by the condensation polymerisation of melamine and formaldehyde. It is used in the manufacture of unbreakable crockery.



Silicon polymers, commonly called silicones, are polymers with a backbone of alternating silicon and oxygen atoms (–Si–O–Si–). Organic groups (like $–CH_3$, $–C_2H_5$) are attached to silicon, giving them unique properties such as flexibility, thermal stability, and water repellency. Silicon is reacted with methyl chloride (CH_3Cl) in the presence of a copper catalyst to produce dimethyldichlorosilane ($[CH_3]_2Si[Cl]_2$).

This reaction involves: $2RCl+Si \rightarrow R_2SiCl_2$



Functional polymers

- Functional polymers are special types of plastics made to do more than just ordinary uses. They are designed with unique properties so they can work in industry, technology, and medicine. For example,
- some are fire-resistant like PVC, which helps prevent burning in buildings and electronics. Others can conduct electricity, such as polyaniline and polythiophene, making them useful in things like sensors, solar cells, and flexible gadgets.
- In medicine, polymers are used in contact lenses (PHEMA), dental fillings (PMMA, Bis-GMA), and even in artificial hearts, kidneys, skin, and blood-related devices using materials like polyurethane and silicone rubber.
- In short, functional polymers are modern materials that make life safer, healthier, and more advanced.

Electrically conducting polymers

- Electrically conducting polymers are special plastics that can carry electricity, unlike normal plastics which are insulators. They work because their structure has alternating single and double bonds, allowing electrons to move freely.
- Their conductivity can be increased by a process called doping (adding certain chemicals). Common examples include polyaniline, polypyrrole, polythiophene, and polyacetylene.
- These polymers are light, flexible, and corrosion-resistant, which makes them useful in batteries, sensors, solar cells, antistatic coatings, and flexible electronic devices.
- There three different types of electrically conducting polymers are known:

1) Ion-Polymer solid electrolyte systems
2) Composites of electronic conducting materials in non-conducting polymer
3) Polymers that can conduct electricity by electronic transport

Fire-retarding polymers

Fire-retarding polymers are polymers that resist burning and reduce fire hazards. They work by slowing down flames, releasing gases that stop fire, or forming a protective layer. Examples

include PVC and melamine–formaldehyde resins, which are used in construction materials, furniture, wires, and electronics for safety.

Mechanisms:

1. **Char Formation:** Forms a protective carbon layer on the surface, preventing oxygen from reaching the polymer.
2. **Gas Release:** Releases non-flammable gases (like HCl, HBr, or nitrogen) that dilute oxygen and slow combustion.
3. **Endothermic Reactions:** Absorbs heat during decomposition, lowering the temperature and slowing the burning process.
4. **Radical Trapping:** Some polymers trap free radicals in flames, stopping the chain reaction of combustion.

Examples:

- PVC (Polyvinyl Chloride): Contains chlorine; commonly used in pipes, wires, and cables.
- Melamine–Formaldehyde Resins: Release nitrogen-rich gases; used in laminates, furniture, and coatings.
- Polybrominated Polymers: Contain bromine; used in electronics and textiles for flame resistance.
- Phosphorus-containing Polymers: Promote char formation and inhibit fire spread.

Biomedical polymers

Biomedical polymers are specially designed polymers that are biocompatible, sometimes biodegradable, and suitable for interacting with living tissues. They are widely used in medical devices, implants, drug delivery systems, and tissue engineering. For examples-

Contact lenses are made from PHEMA (polyhydroxyethyl methacrylate) or silicone hydrogels, which are transparent, flexible, oxygen-permeable, and comfortable for long-term wear.

Dental polymers such as PMMA and Bis-GMA are used in dentures, tooth fillings, crowns, and adhesives due to their biocompatibility, durability, and aesthetic appeal.

Artificial hearts require polymers like polyurethane, PTFE (Teflon), and Dacron (PET), which are non-thrombogenic and durable under continuous pumping, and are used in heart valves and assist devices.

Artificial kidneys or dialysis membranes use polymers such as cellulose acetate, polysulfone, and polyacrylonitrile, which are biocompatible, highly permeable, and stable in blood contact, allowing selective removal of toxins.

Artificial skin employs silicone rubber, collagen-polymer composites, and hydrogels (PEG, PHEMA) to protect tissue, promote healing, and support cell growth.

Polymers are also used in blood bags and blood substitutes, with PVC providing flexibility and perfluorocarbon-based polymers acting as artificial oxygen carriers. Other applications include drug delivery systems using biodegradable polymers like PLA and PLGA, tissue engineering scaffolds for bone, cartilage, or organ growth, and surgical implants such as plates, screws, and stents.

Important features of biomedical polymers include biocompatibility, optional biodegradability, flexibility, durability, chemical stability in biological environments, and the ability to mimic natural tissues or provide mechanical support.

1. Which of the following polymers is highly flexible and widely used in packaging?

A) Polyethylene

B) Polyvinyl chloride

C) Polyamides

D) Phenolic resin

Ans: A) Polyethylene

2. Which polymer is rigid, self-extinguishing, and resistant to corrosion?

A) Polyethylene

B) Polyvinyl chloride (PVC)

C) Polyesters

D) Epoxy resin

Ans: B) PVC

3. Which polymer has high tensile strength and is used in Fibers like nylon?

A) Polyesters

B) Polyamides

C) Phenolic resin

D) Silicon polymer

Ans: B) Polyamides

4. Which polymer is known for excellent adhesion and electrical insulation?

A) Epoxy resin

B) Polyethylene

C) Polyvinyl chloride

D) Polyamides

Ans: A) Epoxy resin

5. Which polymer has a backbone of –Si–O– and is flexible and heat resistant?

A) Polyamide

B) Silicon polymer (Silicone)

C) Polyester

D) Polyvinyl chloride

Ans: B) Silicon polymer

6. Which polymer is brittle, heat resistant, and used in molding electrical switches?

A) Polyamide

B) Phenolic resin

C) Epoxy resin

D) Polyethylene

Ans: B) Phenolic resin

7. Fire-retardant polymers work mainly by:

A) Conducting electricity

B) Forming a protective char layer

C) Absorbing water

D) Dissolving in flame

Ans: B) Forming a protective char layer

8. Which of the following is an electrically conducting polymer?

A) PVC

B) Polyaniline

C) Polyethylene

D) Phenolic resin

Ans: B) Polyaniline

9. Which polymer is used for making soft contact lenses?

A) Polyethylene

B) Polyacrylamide (hydrogel)

C) Polyvinyl chloride

D) Silicon polymer

Ans: B) Polyacrylamide (hydrogel)

10. Dental polymers are primarily used in:

A) Artificial joints

B) Fillings and dentures

C) Heart valves

D) Kidney dialysis

Ans: B) Fillings and dentures

11. Polymers used in artificial heart, kidney, and skin must be:

A) Electrically conductive

B) Biocompatible

C) Fire retardant

D) Highly brittle

Ans: B) Biocompatible

12. Which polymer is commonly used in blood bags and tubing?

A) Polyvinyl chloride (PVC)

B) Polyamide

C) Polyethylene

D) Epoxy resin

Ans: A) PVC

13. Which polymer is widely used in making plastic bottles and packaging films?

A) Polyvinyl chloride

B) Polyethylene

C) Polyamide

D) Phenolic resin

Ans: B) Polyethylene

14. Which polymer is brittle and heat-resistant, used in electrical switches and handles?

A) Epoxy resin

B) Polyamide

C) Phenolic resin

D) Silicone polymer

Ans: C) Phenolic resin

15. Nylon-6,6 is an example of:

A) Polyester

B) Polyamide

C) Epoxy resin

D) PVC

Ans: B) Polyamide

16. Which polymer is used in insulating cables and PCB laminates?

A) Epoxy resin

B) Polyamide

C) Polyethylene

D) PVC

Ans: A) Epoxy resin

17. Which polymer can be softened by plasticizers to make flexible sheets?

A) PVC

B) Polyamide

C) Polyethylene

D) Phenolic resin

Ans: A) PVC

18. Silicone polymers are also called:

A) Polysiloxanes

B) Polyesters

C) Polyamides

D) Polyolefins

Ans: A) Polysiloxanes

19. Fire-retardant polymers usually contain:

A) Sulfur

B) Halogens, phosphorus, or nitrogen

C) Oxygen only

D) Silicon

Ans: B) Halogens, phosphorus, or nitrogen

20. Polythiophene, polyaniline, and polypyrrole are examples of:

A) Fire-retardant polymers

B) Electrically conducting polymers

C) Biomedical polymers

D) Thermosetting resins

Ans: B) Electrically conducting polymers

21. Doping of conducting polymers is used to:

A) Increase thermal stability

B) Increase electrical conductivity

C) Make them fire-retardant

D) Improve biocompatibility

Ans: B) Increase electrical conductivity

22. Soft contact lenses are made from:

A) Polyethylene

B) Hydrogel (polyacrylamide)

C) Polypropylene

D) PVC

Ans: B) Hydrogel (polyacrylamide)

23. Which polymer is used in artificial heart valves?

A) Biocompatible polyurethanes

B) Polyethylene

C) Polyvinyl chloride

D) Polyaniline

Ans: A) Biocompatible polyurethanes

24. Materials used for skin grafts or artificial skin must be:

A) Electrically conducting

B) Biocompatible and flexible

C) Fire-retardant

D) Rigid and brittle

Ans: B) Biocompatible and flexible

25. PVC is used in biomedical applications such as:

A) Dental implants

B) Blood bags and IV tubes

C) Artificial kidneys

D) Pacemakers

Ans: B) Blood bags and IV tubes

26. Dental polymers are mainly:

A) Polyamides

B) Polymethyl methacrylate (PMMA)

C) Polyesters

D) Silicone polymers

Ans: B) Polymethyl methacrylate (PMMA)

27. Polyesters like PET are commonly used in:

A) Electrical insulation

B) Textile fibers and bottles

C) Pipes and fittings

D) Dental polymers

Ans: B) Textile fibers and bottles

28. Which polymer is thermosetting and forms a hard, brittle material on curing?

A) Polyethylene

B) Epoxy resin

C) Phenolic resin

D) PVC

Ans: C) Phenolic resin

29. Polyethylene is:

A) Thermosetting

B) Thermoplastic

C) Electrically conducting

D) Fire-retardant

Ans: B) Thermoplastic

30. PVC becomes flexible when:

A) Heated to 300°C

B) Mixed with plasticizers

C) Polymerized with bisphenol-A

D) Cross-linked with epichlorohydrin

Ans: B) Mixed with plasticizers

31. Nylon-6 is produced by:

A) Condensation of caprolactam

B) Free radical polymerization of ethylene

C) Reaction of epichlorohydrin with bisphenol-A

D) Hydrolysis of chlorosilanes

Ans: A) Condensation of caprolactam

32. Silicone polymers are stable because of:

A) C–C backbone

B) C–O backbone

C) Si–O–Si backbone

D) N–C backbone

Ans: C) Si–O–Si backbone

33. Fire-retardant PVC contains:

A) Fluorine

B) Chlorine

C) Sulfur

D) Hydrogen

Ans: B) Chlorine

34. Which functional polymer is used in antistatic coatings?

A) Polyethylene

B) Polypyrrole

C) Polyamide

D) Phenolic resin

Ans: B) Polypyrrole

35. Conductivity in polymers is achieved by:

A) Hydrogen bonding

B) Conjugated double bonds

C) Halogen substitution

D) Cross-linking with bisphenol-A

Ans: B) Conjugated double bonds

36. Which of the following is a p-type conducting polymer?

A) Polyaniline

B) Polyethylene

C) PVC

D) Phenolic resin

Ans: A) Polyaniline

37. Artificial kidneys use polymers that are:

A) Electrically conducting

B) Biocompatible and semi-permeable

C) Fire-retardant

D) Rigid and brittle

Ans: B) Biocompatible and semi-permeable

38. Polyurethane is used in:

A) Contact lenses

B) Artificial heart valves and blood vessels

C) PVC tubing

D) Dental fillings

Ans: B) Artificial heart valves and blood vessels

39. Polymethyl methacrylate (PMMA) is used in:

A) Bone cement and dental prostheses

B) Electrical insulation

C) Fire-retardant coatings

D) Textile fibers

Ans: A) Bone cement and dental prostheses

40. Hydrogels in contact lenses are made from:

A) Polyethylene

B) Polyacrylamide

C) Polyvinyl chloride

D) Phenolic resin

Ans: B) Polyacrylamide

41. Blood storage bags are mainly made of:

A) Polyethylene

B) Polyvinyl chloride (PVC)

C) Polyamide

D) Epoxy resin

Ans: B) Polyvinyl chloride (PVC)

42. The polymerization of ethylene to polyethylene is an example of:

A) Condensation polymerization

B) Addition (chain-growth) polymerization

C) Copolymerization

D) Cross-linking reaction

Ans: B) Addition (chain-growth) polymerization

43. The reaction of bisphenol-A with epichlorohydrin produces:

A) Phenolic resin

B) Epoxy resin

C) Polyamide

D) Polyethylene

Ans: B) Epoxy resin

44. PET (polyethylene terephthalate) is synthesized by:

A) Condensation of terephthalic acid and ethylene glycol

B) Polymerization of ethylene

C) Reaction of bisphenol-A with epichlorohydrin

D) Hydrolysis of chlorosilanes

Ans: A) Condensation of terephthalic acid and ethylene glycol

45. Phenolic resins are formed by the condensation of:

A) Phenol and formaldehyde

B) Bisphenol-A and epichlorohydrin

C) Caprolactam

D) Ethylene glycol and terephthalic acid

Ans: A) Phenol and formaldehyde

46. Polyamides are characterized by which functional group in the chain?

A) Ester (-COO-)

B) Amide (-CONH-)

C) Ether (-O-)

D) Alkene (-C=C-)

Ans: B) Amide (-CONH-)

47. Polyethylene has the following property:

A) High chemical resistance and low density

B) Rigid and brittle

C) Electrically conductive

D) Thermosetting

Ans: A) High chemical resistance and low density

48. Polyvinyl chloride can be made flexible by:

A) Increasing polymerization temperature

B) Adding plasticizers

C) Copolymerization with ethylene

D) Cross-linking with formaldehyde

Ans: B) Adding plasticizers

49. Fire-retardant polymers work by:

A) Conducting electricity to dissipate heat

B) Forming a char or releasing halogen/phosphorus gases

C) Absorbing water to cool down

D) Decomposing into combustible products

Ans: B) Forming a char or releasing halogen/phosphorus gases

50. Electrically conducting polymers are usually:

A) Saturated polymers with single bonds only

B) Polymers with conjugated π-electron systems

C) Polymers with Si–O–Si backbone

D) Polymers with only ester linkages

Ans: B) Polymers with conjugated π-electron systems

51. Polyaniline becomes conductive by:

A) Heating above 300°C

B) Doping with acids

C) Mixing with PVC

D) Cross-linking with formaldehyde

Ans: B) Doping with acids

52. Polythiophene is used in:

A) Fireproof clothing

B) Organic LEDs and solar cells

C) PVC pipes

D) Dental prosthetics

Ans: B) Organic LEDs and solar cells

53. Artificial skin and wound dressings often use:

A) Polyethylene

B) Biocompatible hydrogels

C) Phenolic resins

D) Polyamides

Ans: B) Biocompatible hydrogels

54. Polyurethane is widely used in:

A) Artificial heart valves, blood vessels, and catheters

B) Electrical insulation

C) PVC tubing

D) Flooring materials

Ans: A) Artificial heart valves, blood vessels, and catheters

55. PMMA (polymethyl methacrylate) is used for:

A) Blood bags

B) Bone cement, dentures, and dental fillings

C) Conductive coatings

D) Fireproof coatings

Ans: B) Bone cement, dentures, and dental fillings

56. Contact lenses are made of:

A) Polyamide fibers

B) Hydrogels like polyacrylamide or HEMA

C) PVC

D) Epoxy resin

Ans: B) Hydrogels like polyacrylamide or HEMA

57. Blood storage bags are made from:

A) Polyamide

B) PVC

C) PMMA

D) Polyethylene

Ans: B) PVC

58. Artificial kidneys use membranes made from:

A) Electrically conductive polymers

B) Biocompatible semi-permeable polymers

C) Fire-retardant PVC

D) Phenolic resin

Ans: B) Biocompatible semi-permeable polymers

59. Dental polymers commonly used are:

A) Polyamides

B) PMMA

C) Polyethylene

D) Epoxy resins

Ans: B) PMMA

60. Biocompatible polymers must be:

A) Electrically conducting

B) Non-toxic, non-immunogenic, and stable in the body

C) Fire-retardant

D) Thermosetting only

Ans: B) Non-toxic, non-immunogenic, and stable in the body

61. Nylon-6,6 is synthesized from:

A) Hexamethylene diamine and adipic acid

B) Caprolactam only

C) Ethylene and benzene

D) Bisphenol-A and epichlorohydrin

Ans: A) Hexamethylene diamine and adipic acid

62. The main characteristic of thermosetting polymers like phenolic resin is:

A) They soften on heating

B) They are cross-linked and do not melt

C) They are flexible

D) They dissolve in water

Ans: B) They are cross-linked and do not melt

63. Polyesters are biodegradable only if:

A) Aromatic monomers are used

B) Aliphatic monomers are used

C) They are cross-linked

D) They contain silicon

Ans: B) Aliphatic monomers are used

64. Rigid PVC is mainly used in:

A) Electrical cables

B) Pipes, doors, and window frames

C) Flexible sheets

D) Packaging films

Ans: B) Pipes, doors, and window frames

65. Plasticized PVC is used for:

A) Pipes and fittings

B) Flooring, raincoats, and blood bags

C) Nylon fibers

D) Phenolic mouldings

Ans: B) Flooring, raincoats, and blood bags

66. Epoxy resin becomes hard due to:

A) Polymerization of bisphenol-A

B) Curing with hardeners (amines or anhydrides)

C) Mixing with plasticizers

D) Hydrolysis with water

Ans: B) Curing with hardeners (amines or anhydrides)

67. Silicone polymers are highly heat resistant because of:

A) C–C bonds in the backbone

B) Si–O–Si bonds in the backbone

C) Amide groups

D) Phenolic rings

Ans: B) Si–O–Si bonds in the backbone

68. Which of the following is a halogen-containing fire-retardant polymer?

A) Polyethylene

B) PVC

C) Nylon

D) Epoxy resin

Ans: B) PVC

69. Conducting polymers require doping to:

A) Improve mechanical strength

B) Enhance electrical conductivity

C) Increase thermal stability

D) Reduce molecular weight

Ans: B) Enhance electrical conductivity

70. Polypyrrole is used in:

A) Fire-retardant coatings

B) Antistatic coatings and flexible electronics

C) Contact lenses

D) Blood bags

Ans: B) Antistatic coatings and flexible electronics

71. Polyaniline can switch between conducting and insulating states due to:

A) Hydrogen bonding

B) Doping and de-doping

C) Cross-linking

D) Plasticization

Ans: B) Doping and de-doping

72. Which functional polymer is used in organic solar cells?

A) PVC

B) Polythiophene

C) PMMA

D) Polyamide

Ans: B) Polythiophene

73. Hydrogels used in contact lenses are mainly:

A) Polyethylene

B) Polyacrylamide or HEMA

C) Polystyrene

D) Epoxy resin

Ans: B) Polyacrylamide or HEMA

74. PMMA is commonly used in:

A) Dental prostheses and bone cement

B) Blood bags

C) Conductive coatings

D) Silicone sealants

Ans: A) Dental prostheses and bone cement

75. Biocompatible polymers used in artificial heart valves include:

A) PVC

B) Polyurethane

C) Polystyrene

D) Epoxy resin

Ans: B) Polyurethane

76. Which polymer is used for blood storage bags and IV tubes?

A) Polyamide

B) PVC

C) PMMA

D) Polyurethane

Ans: B) PVC

77. Artificial kidneys use membranes made of:

A) Biocompatible semi-permeable polymers

B) Polyamide fibers

C) Phenolic resin

D) Silicone polymers

Ans: A) Biocompatible semi-permeable polymers

78. Dental polymers like PMMA are preferred because they are:

A) Electrically conductive

B) Biocompatible, non-toxic, and durable

C) Fire-retardant

D) Thermosetting only

Ans: B) Biocompatible, non-toxic, and durable

79. Polyurethane is also used in:

A) Artificial blood vessels and catheters

B) Electrical cable insulation

C) Flooring sheets

D) Contact lenses

Ans: A) Artificial blood vessels and catheters

80. Hydrogels in biomedical applications are mainly used because they:

A) Conduct electricity

B) Absorb water and mimic soft tissue

C) Are fire-resistant

D) Are rigid and heat resistant

Ans: B) Absorb water and mimic soft tissue

Sample Paper

1. The basic structural unit of a polymer is called:

a) Monomer

b) Repeat unit

c) Copolymer

d) Degree of polymerization

Ans: b) Repeat unit

2. Which polymer is formed by condensation polymerization?

a) Polyethylene

b) Polyvinyl chloride

c) Nylon-6,6

d) Polystyrene

Ans: c) Nylon-6,6

3. The degree of polymerization is defined as:

a) Number of side chains in polymer

b) Number of repeat units in a polymer chain

c) Molecular weight of monomer

d) Density of polymer

Ans: b) Number of repeat units in a polymer chain

4. Radical chain polymerization is generally initiated by:

a) Heat

b) Light

c) Peroxides

d) All of the above

Ans: d) All of the above

5. classified on the basis of molecular force include:

a) Thermoplastics, thermosets, fibres, elastomers

b) Addition, condensation polymers

c) Linear, branched, crosslinked

d) Natural, synthetic

Ans: a) Thermoplastics, thermosets, fibres, elastomers

5. Polydispersity index (PDI) is the ratio of:

a) Number average M_W / Weight average M_W

b) Weight average M_W / Number average M_W

c) Viscosity average M_W / Weight average M_W

d) None of these

Ans: b) Weight average M_W / Number average M_W

6. Osmotic pressure method is used to determine:

a) Viscosity average molecular weight

b) Number average molecular weight

c) Weight average molecular weight

d) Polydispersity index

Ans: b) Number average molecular weight

7. Which technique is best for studying polymer crystallinity?

a) NMR spectroscopy

b) UV-Vis spectroscopy

c) X-ray diffraction

d) Osmometry

Ans: c) X-ray diffraction

8. A polymer has T_g = 100 °C and T_m = 250 °C. Approximate relationship:

a) $T_g \approx T_m /2$

b) $T_g \approx T_m /3$

c) $T_g \approx T_m$

d) No relation

Ans: a) $T_g \approx T_m /2$

9. Viscosity average molecular weight is determined using:

a) Intrinsic viscosity measurement

b) Osmotic pressure

c) Light scattering

d) End group analysis

Ans: a) Intrinsic viscosity measurement

10. A key mechanical property test for polymers under repeated stress is:

a) Tensile strength

b) Impact strength

c) Fatigue test

d) Hardness test

Ans: c) Fatigue test

11. The crystalline melting point of a polymer is denoted by:

a) T_g

b) T_c

c) T_m

d) T_d

Ans: c) T_m

12. The glass transition temperature (T_g) represents:

a) Crystalline melting temperature

b) Onset of polymer degradation

c) Transformation from glassy to rubbery state

d) Boiling point of polymer

Ans: c) Transformation from glassy to rubbery state

13. Which factor increases T_g of a polymer?

a) Increased chain flexibility

b) Increased plasticizer content

c) Cross-linking

d) Addition of diluents

Ans: c) Cross-linking

14. Strain-induced morphology in polymers is associated with:

a) Glass transition

b) Stress crystallization

c) Melting point increase

d) Random coil formation

Ans: b) Stress crystallization

15. Which polymer processing technique can continuously produce long pipes?

a) Injection moulding

b) Extrusion moulding

c) Blow moulding

d) Thermoforming

Ans: b) Extrusion moulding

16. Injection moulding is suitable for producing:

a) Thin sheets

b) Complex 3D shaped products

c) Fibres

d) Films

Ans: b) Complex 3D shaped products

17. The process used to make plastic films is:

a) Blow moulding

b) Extrusion

c) Film casting

d) Rotational moulding

Ans: c) Film casting

18. Elastomers are generally processed by:

a) Fibre spinning

b) Foaming

c) Vulcanization

d) Extrusion only

Ans: c) Vulcanization

19. Fibre spinning involves conversion of:

a) Solid → liquid

b) Polymer melt/solution → fibres

c) Elastomer → sheet

d) Powder → mould

Ans: b) Polymer melt/solution → fibres

20. Thermoforming is mainly used for:

a) Engineering plastics

b) Thin packaging materials

c) Vulcanized rubber

d) High-density polymers

Ans: b) Thin packaging materials

21. Polyethylene is classified as a:

a) Condensation polymer

b) Addition polymer

c) Elastomer

d) Fibre

Ans: b) Addition polymer

22. A polymer sample contains the following molecular species:

20 molecules of MW 10,000

30 molecules of MW 20,000

50 molecules of MW 40,000

The number average molecular weight (M_n) is:

a) 24,000

b) 28,000

c) 32,000

d) 36,000

Ans: a) 24,000

(Calculation: $M_n = \Sigma NiMi / \Sigma Ni = (20\times10,000 + 30\times20,000 + 50\times40,000) / 100 = 2.4\times10^6 / 100 = 24,000$)

23. The monomer of Nylon-6,6 is:

a) Caprolactam

b) Hexamethylene diamine + Adipic acid

c) Terephthalic acid + Ethylene glycol

d) Acrylonitrile

Ans: b) Hexamethylene diamine + Adipic acid

24. Epoxy resins are widely used as:

a) Plasticizers

b) Adhesives and coatings

c) Textile fibres

d) Films

Ans: b) Adhesives and coatings

25. A polymer used in artificial heart valves is:

a) Polyethylene

b) Silicone rubber

c) Phenolic resin

d) Polyvinyl chloride

Ans: b) Silicone rubber

26. Conducting polymers include:

a) Polyacetylene, polyaniline

b) Polyethylene, polypropylene

c) Epoxy resins, phenolics

d) Nylon, polyester

Ans: a) Polyacetylene, polyaniline

27. If the degree of polymerization (DP) of a polyethylene sample is 50,000, the approximate molecular weight is:

(Molecular weight of ethylene monomer = 28 g/mol)

a) 1.4×10^3 g/mol

b) 1.4×10^5 g/mol

c) 2.8×10^5 g/mol

d) 5.0×10^5 g/mol

Ans: b) 1.4×10^5 g/mol

(Calculation: M_W = DP × monomer M_W = 50,000 × 28 = 1.4×10^6 g/mol → 1.4×10^5 g/mol if given in $\times 10^5$ form)

28. For the same data, the weight average molecular weight (M_w) is:

a) 28,000

b) 30,000

c) 32,000

d) 34,000

Ans: c) 32,000

(Calculation: $M_w = \Sigma N_i M_i^2 / \Sigma N_i M_i = (20\times10{,}000^2 + 30\times20{,}000^2 + 50\times40{,}000^2) / 2.4\times10^6 = 7.68\times10^{10} / 2.4\times10^6 = 32{,}000$)

29. The polydispersity index (PDI) for this polymer sample is:

a) 1.25

b) 1.33

c) 1.50

d) 2.00

Ans: b) 1.33

(Calculation: $PDI = M_w/M_n = 32{,}000 / 24{,}000 = 1.33$)

30. If a polymer solution shows intrinsic viscosity $[\eta] = 0.5$ dL/g, and the Mark–Houwink constants are $K = 1.0 \times 10^{-4}$ dL/g and $a = 0.8$, the viscosity average molecular weight (Mv) is:

a) 2.0×10^4

b) 2.5×10^4

c) 3.0×10^4

d) 4.0×10^4

Ans: b) 2.5×10^4

(Calculation: $[\eta] = K M^a \rightarrow 0.5 = 1\times10^{-4} \times M^{0.8} \rightarrow M^{0.8} = 5000 \rightarrow M = (5000)^{(1/0.8)} \approx 2.5\times10^4$)

31. If T_g of a polymer is 120 °C, addition of a plasticizer reduces T_g by 30%. The new T_g is:

a) 96 °C

b) 84 °C

c) 60 °C

d) 40 °C

Ans: b) 84 °C

(Calculation: T_g reduced = 120 – (0.3×120) = 84 °C)

32. Which of the following is a step-growth polymerization?

a) Polyethylene formation

b) Polystyrene formation

c) Nylon-6,6 formation

d) Polyvinyl chloride formation

Ans: c) Nylon-6,6 formation

33. Linear polymers usually show:

a) High tensile strength

b) Low density

c) High crystallinity

d) All of the above

Ans: d) All of the above

34. Which of the following is NOT a classification basis for polymers?

a) Source (natural/synthetic)

b) Mode of polymerization

c) Crystallinity

d) Boiling point

Ans: d) Boiling point

35. Coordination polymerization is catalysed by:

a) Ziegler–Natta catalysts

b) Free radicals

c) Peroxides

d) Sulfur

Ans: a) Ziegler–Natta catalysts

36. Branched polymers compared to linear polymers generally have:

a) Higher density

b) Lower melting point

c) Greater crystallinity

d) Higher tensile strength

Ans: b) Lower melting point

37. A polymer crystallizes with $\Delta H_f = 150$ J/g. If the crystallinity measured is 60%, the effective heat of fusion is:

a) 60 J/g

b) 75 J/g

c) 90 J/g

d) 120 J/g

Ans: c) 90 J/g

(Calculation: $150 \times 0.6 = 90$ J/g)

38. In injection moulding, if a part requires 200 cm^3 of molten polymer and the machine delivers at a rate of 20 cm^3/s, the minimum injection time is:

a) 5 s

b) 8 s

c) 10 s

d) 15 s

Ans: c) 10 s

(Calculation: Time = Volume/Rate = 200/20 = 10 s)

39. A fibre spinning process converts 1 kg of polymer into fibres. If the fibre density = 1.2 g/cm^3, the total fibre volume is:

a) 600 cm^3

b) 800 cm^3

c) 833 cm^3

d) 1000 cm^3

Ans: c) 833 cm^3

(Calculation: Volume = Mass/Density = 1000 g / 1.2 g/cm³ = 833 cm³)

40. Polydispersity of a polymer sample arises due to:

a) Same chain length for all molecules

b) Different chain lengths present

c) Cross-linking only

d) Presence of fillers

Ans: b) Different chain lengths present

41. Which technique is most useful to study molecular weight distribution?

a) Light scattering

b) Gel permeation chromatography (GPC)

c) End-group analysis

d) Osmotic pressure method

Ans: b) Gel permeation chromatography (GPC)

42. Thermal analysis of polymers is performed by:

a) UV-Vis spectroscopy

b) Differential scanning calorimetry (DSC)

c) FTIR spectroscopy

d) Optical microscopy

Ans: b) Differential scanning calorimetry (DSC)

43. The property that measures resistance of a polymer to sudden force is:

a) Fatigue

b) Impact strength

c) Hardness

d) Abrasion resistance

Ans: b) Impact strength

44. Which test is used to measure polymer resistance to scratching?

a) Tensile test

b) Impact test

c) Hardness test

d) Tear test

Ans: c) Hardness test

45. Amorphous polymers are generally:

a) Transparent

b) Opaque

c) Crystalline

d) Brittle at all temperatures

Ans: a) Transparent

46. Which polymer property is influenced most by crystallinity?

a) Thermal conductivity

b) Optical clarity

c) Melting point

d) Electrical conductivity

Ans: c) Melting point

47. Above T_g, polymers behave as:

a) Brittle solids

b) Rubbery materials

c) Crystalline solids

d) Fluids

Ans: b) Rubbery materials

48. Which factor decreases T_g?

a) Cross-linking

b) Bulky side groups

c) Addition of plasticizers

d) Strong intermolecular forces

Ans: c) Addition of plasticizers

49. Entropy of fusion during melting of crystalline polymers is:

a) Zero

b) Positive

c) Negative

d) Infinite

Ans: b) Positive

50. Blow moulding is used for manufacturing:

a) Plastic bottles

b) Thin films

c) Sheets

d) Fibres

Ans: a) Plastic bottles

51. Calendering is most suitable for:

a) PVC sheets

b) PET bottles

c) Nylon fibres

d) Polyethylene pipes

Ans: a) PVC sheets

52. In extrusion moulding, the polymer is:

a) Forced through a die

b) Blown with compressed air

c) Cast on a flat plate

d) Expanded with foaming agents

Ans: a) Forced through a die

53. Foamed polymers are used for:

a) Optical lenses

b) Cushioning and insulation

c) Fibres

d) High-strength structures

Ans: b) Cushioning and insulation

54. Terylene (PET) is a:

a) Polyester

b) Polyamide

c) Polyolefin

d) Phenolic resin

Ans: a) Polyester

55. Bakelite is a:

a) Polyamide

b) Phenol-formaldehyde resin

c) Polyvinyl polymer

d) Polyolefin

Ans: b) Phenol-formaldehyde resin

56. Silicone polymers are unique because they:

a) Have Si–O–Si backbone

b) Have high electrical conductivity

c) Are biodegradable

d) Are always crystalline

Ans: a) Have Si–O–Si backbone

57. Which polymer is commonly used for bulletproof materials?

a) Polyethylene

b) Kevlar (aramid)

c) PVC

d) Epoxy resin

Ans: b) Kevlar (aramid)

58. A common biomedical use of polymethyl methacrylate (PMMA) is:

a) Artificial bone cement

b) Contact lenses

c) Coatings

d) Sutures

Ans: b) Contact lenses

59. Conducting polymers are mainly used in:

a) Food packaging

b) Solar cells and sensors

c) Cushioning foams

d) Textile fibres

Ans: b) Solar cells and sensors

60. Which of the following is a natural polymer?

a) Polystyrene

b) Polyethylene

c) Cellulose

d) PVC

Ans: c) Cellulose

61. Addition polymerization generally involves:

a) Loss of small molecules like water

b) Free radical chain growth

c) Stepwise condensation

d) Ionic degradation

Ans: b) Free radical chain growth

62. Which of the following is a copolymer?

a) Polystyrene

b) Nylon-6

c) SBR (styrene–butadiene rubber)

d) PVC

Ans: c) SBR (styrene–butadiene rubber)

63. Network polymers are best described as:

a) Thermoplastics

b) Elastomers

c) Highly cross-linked structures

d) Linear chains

Ans: c) Highly cross-linked structures

64. Thermoplastics differ from thermosets in that they:

a) Are highly cross-linked

b) Can be remelted and reshaped

c) Have higher thermal stability

d) Cannot be recycled

Ans: b) Can be remelted and reshaped

65. Which method directly measures molecular weight without calibration standards?

a) GPC

b) Osmotic pressure

c) Intrinsic viscosity

d) End-group analysis

Ans: b) Osmotic pressure

66. Which property is tested by abrasion resistance?

a) Wear and tear under friction

b) Resistance to impact

c) Flexibility

d) Transparency

Ans: a) Wear and tear under friction

67. Which average molecular weight is most sensitive to high molecular weight species?

a) Number average (M_n)

b) Weight average (M_w)

c) Viscosity average (M_v)

d) All equally sensitive

Ans: b) Weight average (M_w)

68. Which technique gives information on polymer microstructure?

a) Light scattering

b) NMR spectroscopy

c) Osmometry

d) Ultracentrifugation

Ans: b) NMR spectroscopy

69. Which polymer property is largely influenced by chain flexibility?

a) Tensile strength

b) Glass transition temperature

c) Density

d) Electrical conductivity

Ans: b) Glass transition temperature

70. Spherulites are:

a) Cross-linking agents

b) Crystalline regions in polymers

c) Plasticizers

d) Chain ends

Ans: b) Crystalline regions in polymers

71. Glass transition is best described as a:

a) First-order transition

b) Second-order transition

c) Melting process

d) Decomposition

Ans: b) Second-order transition

72. The process of shaping polymer using vacuum over a mould is:

a) Injection moulding

b) Thermoforming

c) Calendering

d) Compression moulding

Ans: b) Thermoforming

73. Which processing technique is most suitable for producing fibres?

a) Blow moulding

b) Fibre spinning

c) Film casting

d) Rotational moulding

Ans: b) Fibre spinning

74. Rotational moulding is typically used for:

a) Hollow objects like tanks

b) Thin plastic films

c) PVC sheets

d) Plastic bottles

Ans: a) Hollow objects like tanks

75. Compounding of polymers generally involves:

a) Mixing fillers, stabilizers, and colorants

b) Polymerization reaction

c) Thermal degradation

d) Fibre spinning

Ans: a) Mixing fillers, stabilizers, and colorants

76. Dacron is a trade name for:

a) Nylon-6

b) Polyethylene

c) PET (polyethylene terephthalate)

d) PVC

Ans: c) PET (polyethylene terephthalate)

77. Teflon is:

a) Polyvinyl chloride

b) Polytetrafluoroethylene (PTFE)

c) Polypropylene

d) Polyurethane

Ans: b) Polytetrafluoroethylene (PTFE)

78.Which polymer is most suitable for electrical insulation?

a) Polyethylene

b) Phenol–formaldehyde resin

c) Silicone rubber

d) All of the above

Ans: d) All of the above

79. Which biomedical polymer is commonly used in artificial kidneys?

a) Polypropylene

b) Cellulose acetate

c) Nylon-6,6

d) Polystyrene

Ans: b) Cellulose acetate

80. The first synthetic polymer produced industrially was:

a) PVC

b) Bakelite

c) Nylon

d) Polyester

Ans: b) Bakelite

81. The repeating unit of polyvinyl chloride (PVC) has a molecular weight of 62.5 g/mol. If the degree of polymerization (DP) = 1000, then M_W = ?

a) 6.25×10^3

b) 6.25×10^4

c) 6.25×10^5

d) 6.25×10^6

Ans: c) 6.25×10^5

(Calculation: $M_W = 1000 \times 62.5 = 62,5000 = 6.25 \times 10^5$ g/mol)

82. If polyethylene has a density of 0.92 g/cm³ and polypropylene has 0.90 g/cm³, which statement is correct?

a) Polypropylene is denser

b) Polyethylene is denser

c) Both have equal density

d) None

Ans: b) Polyethylene is denser

83. A sample of Nylon-6,6 has M_W = 30,000. If each repeat unit has M_W = 226, the degree of polymerization is:

a) 120

b) 133

c) 145

d) 160

Ans: b) 133 (Calculation: DP = 30,000 / 226 ≈ 133)

84. Condensation polymerization generally requires:

a) High pressure only

b) Elimination of small molecules like H_2O or HCl

c) Free radical initiator

d) Ziegler–Natta catalyst

Ans: b) Elimination of small molecules like H_2O or HCl

85. Polymers made of two or more different monomers are called:

a) Homopolymers

b) Copolymers

c) Block polymers

d) Linear polymers

Ans: b) Copolymers

86. Which type of polymer has high elasticity and can regain shape after deformation?

a) Thermoplastics

b) Elastomers

c) Thermosets

d) Fibres

Ans: b) Elastomers

87. Cross-linked polymers are generally:

a) Soluble in organic solvents

b) Insoluble and infusible

c) Easily recyclable

d) Linear and crystalline

Ans: b) Insoluble and infusible

88. Number average molecular weight (M_n) is measured by:

a) End-group analysis

b) Osmotic pressure

c) Both a and b

d) Viscosity measurement

Ans: c) Both a and b

89. Light scattering is primarily used to determine:

a) M_n

b) M_w

c) PDI

d) None

Ans: b) M_w

90. The ratio M_w/M_n is always:

a) Less than 1

b) Equal to 1

c) Greater than or equal to 1

d) Independent of molecular weight distribution

Ans: c) Greater than or equal to 1

91. Polymers with high crystallinity are generally:

a) Transparent

b) Brittle

c) Stronger and denser

d) More flexible

Ans: c) Stronger and denser

92. The term "morphology" of polymers refers to:

a) Molecular weight distribution

b) Shape and arrangement of crystalline and amorphous regions

c) Polymerization mechanism

d) Monomer type

Ans: b) Shape and arrangement of crystalline and amorphous regions

93. Which transition is associated with heat capacity change but no latent heat?

a) Melting

b) Decomposition

c) Glass transition

d) Crystallization

Ans: c) Glass transition

94. Nylon is a:

a) Polyamide

b) Polyester

c) Phenolic resin

d) Polyolefin

Ans: a) Polyamide

95. Which polymer is widely used for packaging films?

a) Polyethylene

b) Epoxy resin

c) Phenolic resin

d) Silicone

Ans: a) Polyethylene

96. Which polymer is often used for coatings and adhesives?

a) Epoxy resin

b) Nylon

c) PET

d) Polypropylene

Ans: a) Epoxy resin

97. Kevlar, used in bulletproof vests, is:

a) A polyester

b) An aramid fibre

c) A polyolefin

d) A thermoset resin

Ans: b) An aramid fibre

98. Which polymer is known for extreme chemical resistance and non-stick properties?

a) PVC

b) PTFE (Teflon)

c) Nylon-6,6

d) Phenolic resin

Ans: b) PTFE (Teflon)

99. Fibre spinning methods include:

a) Melt spinning

b) Dry spinning

c) Wet spinning

d) All of the above

Ans: d) All of the above

100. Which factor increases Tm of polymers?

a) Flexible chains

b) Bulky side groups

c) Regular stereochemistry (isotactic)

d) Plasticizer addition

Ans: c) Regular stereochemistry (isotactic)

References

- Singh, J., & Dubey, R. C. *Organic polymer chemistry*. Meerut, India: Pragati Prakashan.
- Kheterpal, S. C. *Pradeep physical chemistry (Vol. 3, B.Sc. Part-III, Semesters 5 & 6)*. Jalandhar, India: Pradeep Publications.
- Mahajan, R. S. *Introduction to polymers*.
- Gowariker, V. R., Viswanathan, N. V., & Sreedhar, J. *Polymer science*. New Delhi, India: New Age International.
- Kumar, A., & Gupta, S. K. *Polymer chemistry*. New Delhi, India: New Age International.